TR-277

TECHNICAL REPORT

An Evaluation of the Airborne Expendable Bathythermograph (AXBT, SSQ-36 BTS)

A. Edward Gent

JANUARY 1982

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

PREPARED BY
COMMANDING OFFICER,
NAVAL OCEANOGRAPHIC OFFICE
NSTL STATION, BAY ST. LOUIS, MS 39522

PREPARED FOR
COMMANDER,
NAVAL OCEANOGRAPHY COMMAND
NSTL STATION, BAY ST. LOUIS, MS 39529

FOREWORD

The effort described in this report was performed by engineers and technicians in the Maintenance Engineering Division of the Engineering Department, Naval Oceanographic Office. This work was done in support of the Ocean Measurements Project to provide instrument characteristics data for use by scientists engaged in project related oceanographic measurement. If further information or discussion on this topic is desired contact Commanding Officer, Naval Oceanographic Office, Attention Mr. Adolph H. Klein, Code 6300, NSTL Station, Bay St. Louis, MS 39522, 601-688-4465 (FTS 494-4465, AV 485-4465).

C. H. BASSETT
Captain, USN
Commanding Officer

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER TR-277	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EVALUATION OF THE AIRBORNE EXPENDABLE BATHYTHERMOGRAPH (AXBT, SSQ-36 BTS) Temperature Accuracy and Time Response		5. TYPE OF REPORT & PERIOD COVERED Final 4/80 - 6/81 6. PERFORMING ORG. REPORT NUMBER TR 6300-1-81
7. AUTHOR(s) A. EDWARD GENT		8. CONTRACT OR GRANT NUMBER(s) N/A
9. PERFORMING ORGANIZATION NAME AND ADDRESS Maintenance Engineering Division Naval Oceanographic Office NSTL Station, Bay St. Louis, MS 39522		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS OMP
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Oceanography Command NSTL Station, Bay St. Louis, MS 39529		12. REPORT DATE 6/81 13. NUMBER OF PAGES 147
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) See #11		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AXBT, SSQ-36 BTS, AXBT Temperature Error

AXBT Time Response

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Random samples from lots of AXBTs manufactured by the Hermes, Sippican and Magnavox Corporations were tested for temperature accuracy and time response using precision laboratory facilities. Results, conclusions and correction algorithms are presented.

TABLE OF CONTENTS

FIGURES

PAGE

APPENDIXES

* Tables and curve fits 3 - 137 deleted from this copy.
Copies will be made available upon request.

INTRODUCTION

In support of the Ocean Measurement Project (OMP) the Technical Services Branch of the Naval Oceanographic Office (NAVOCEANO) conducted temperature tests on a number of Airborne Expendable Bathythermographs, Transmitting Model AN/SSQ-36BTS (AXBT). The units, tested by the Maintenance Engineering Division, were from lots manufactured by the Hermes, Sippican and Magnavox Corporations.

Background

When deployed from an aircraft into the sea the AXBT upon impact jettisons its stabilizer parachute assembly, erects a transmitting antenna, and after a short delay for battery activation by salt water, releases a temperature probe. The probe descends at a nominal rate of 1.52m/sec (5 ft/sec). During its descent, an audio modulated VHF signal proportional to the sea temperature is transmitted to the aircraft. The AXBTs have a specified accuracy of $\pm .5^{\circ}C$. After the probe has descended to its maximum depth the units self-scuttle.

While all the AXBTs are deployed in a similar manner their design aspects and operational parameters differ according to the manufacturer (figures 1 - 3). The Sippican unit (figure 2) employs a flotation bag inflated by a CO_2 cartridge fired upon battery activation and release of their outer casing. The Hermes and Magnavox units (figures 1 and 3, respectively) on the other hand, maintain buoyancy with an air-tight electronics compartment which includes the outer casing. All units deploy a monopole antenna for data transmission. The Sippican AXBT is designed to operate to a depth of 762m (2500 ft) while the Magnavox and Hermes models operate to a depth of 305m (1000 ft). Automatic scuttling is accomplished in the Hermes unit by means of a salt water soluble plug in the water tight electronics housing. The Sippican AXBT employs a resistive heater wire that burns a hole in the unit's floatation bag. The Magnavox unit uses a technique similar to Sippican's to burn a hole in a scuttle plug located in the side of the bouyant electronics compartment.

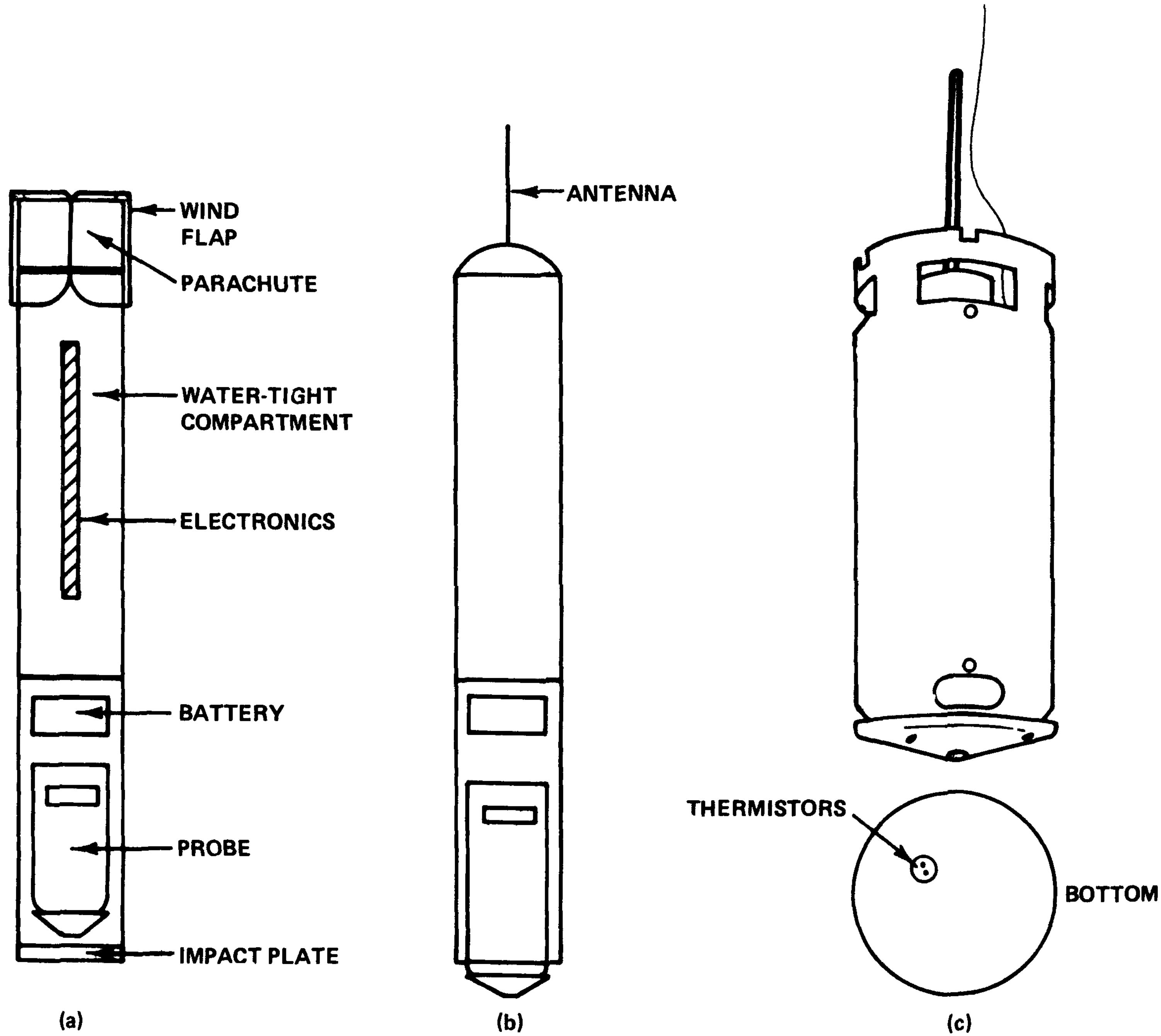


Figure 1 Hermes AXBT

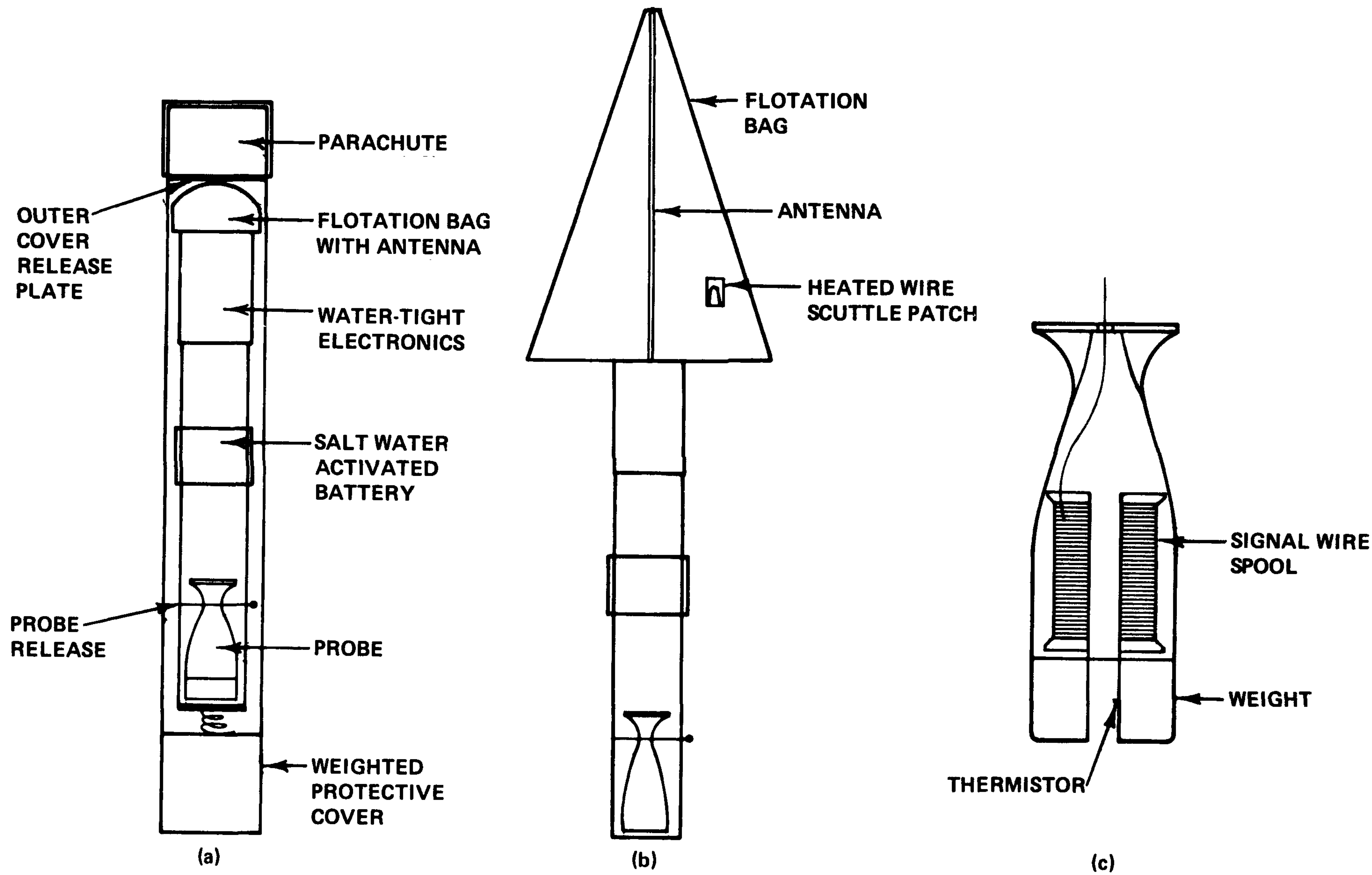


Figure 2 Sippican AXBT

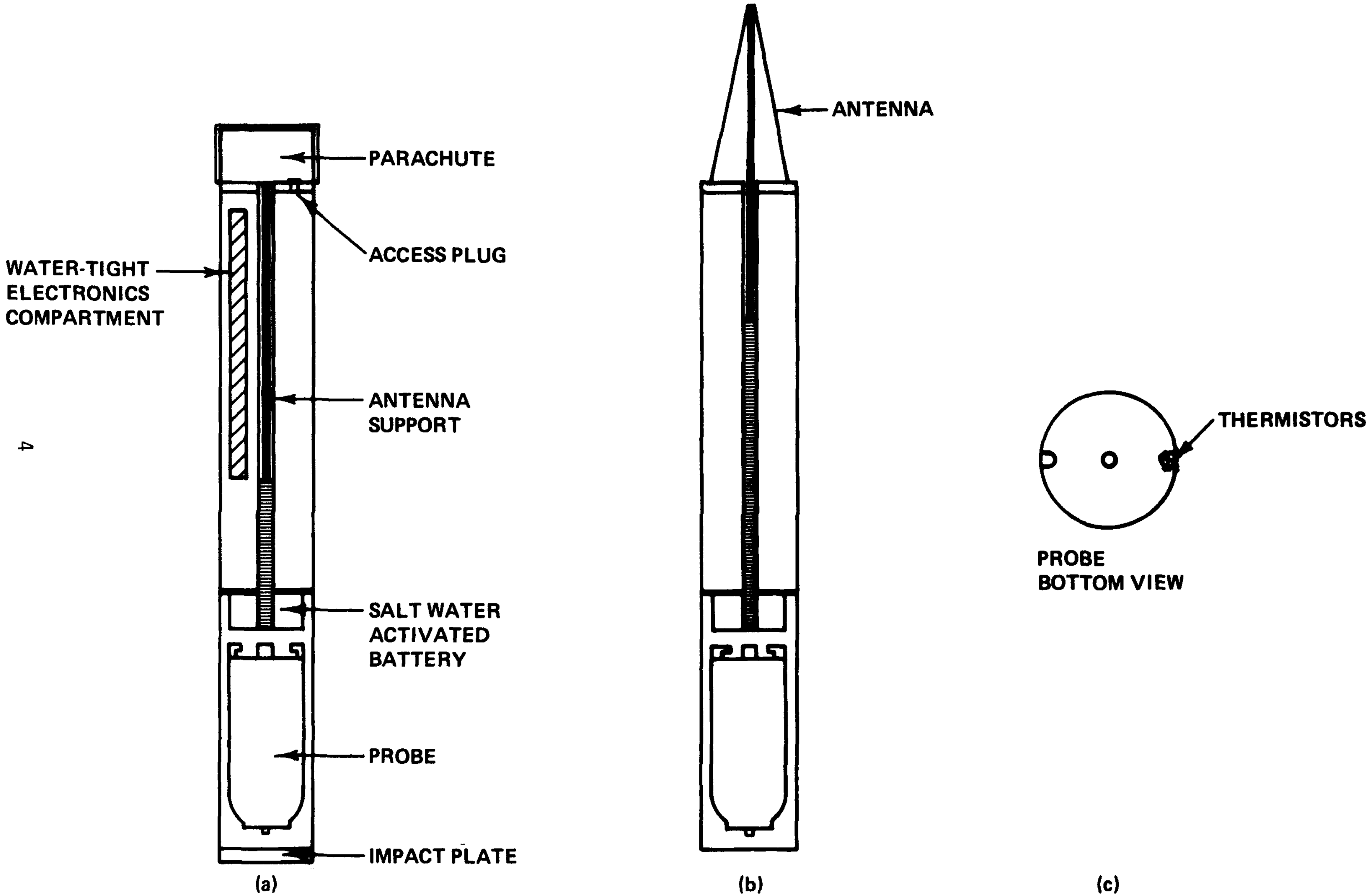


Figure 3 Magnavox AXBT

TEST PROCEDURE

Hermes - Preliminary

Between March 10 and 26, 1980, 56 AXBTs (Model AN/SSQ-36BTS) manufactured by Hermes Electronics Limited were tested. Thirty-one units were from Lot 45 and 25 units from Lot 47. An additional 64 AXBTs were tested between June 5 and 16, 1980. Twenty-eight units were from Lot 39, 27 units from Lot 43 and 9 units from Lot 45.

When the AXBTs were unpacked, it was discovered that there were no unique serial numbers for each unit. To provide test reference numbers, each unit was arbitrarily assigned a "serial number". The units tested in March were numbered 1 through 56. Numbers 101-164 were used to designate the units tested in June.

To facilitate testing and preserve the integrity of the units for future deployment, the parachute assembly was removed to gain access to the electrical test plug located on top of the AXBT housing. The test plug supplied an audio frequency signal proportional to the temperature ($f = 1440 + 36T$) and provided the input for applying an external power source to the probe, by-passing the sea water activated battery. The bottom plate was also removed, with care taken not to deploy the probe assembly. When the bottom plate was removed, about 3" of the probe was exposed below the AXBT's external housing.

Sippican - Preliminary

Between December 5 and 15, 1980, 48 Sippican AXBTs were tested. These units bore no lot designation and were identified by the manufacturers serial number.

During the test, the parachute assemblies and outer casings were removed exposing the operational portion of the units, including the flotation bag with antenna and scuttle patch, the transmitter and electronics package, the salt water activated battery, the jack for applying an external power source, and the temperature probe (figure 2).

Magnavox - Preliminary

Fifty-four Magnavox AXBTs were tested between January 19 and 27, 1981. Of these, 29 units were from Lot 5, 7 from Lot 1, 1 from Lot 7 and 3 from Lot 11, 10 from Lot 19 and 3 from Lot 21. Each AXBT was identified by the manufacturers serial number.

The parachute assembly and bottom impact plate were removed to aid in testing. This allowed access to the test plug for applying an external power source, exposed the temperature probe, and enabled deployment of the antenna.

General Measurement Technique

Proceeding on the premise that the AXBTs should be tested in a non-destructive manner so that they could later be used in actual field deployment, the measurement system shown in figure 4 was developed for the Hermes units and that of figure 5 for the Sippican and Magnavox units.

A variable power supply was used to provide the operating voltage through an external test jack installed by each manufacturer to bypass the salt water activated battery. The supply voltage, monitored with a digital voltmeter, was varied on randomly selected units to determine output dependency on supply voltage. Test data for the Hermes AXBTs were obtained by directly measuring the audio signal proportional to the temperature since this signal was readily available at the test plug. In subsequent testing of the Sippican and Magnavox units a VHF receiver was used to receive the actual AXBT transmission and strip off the audio modulation proportional to the bath temperature. The audio signals were measured by a Hewlett Packard (HP) 5323A counter under the control of a HP9830 desktop calculator.* The counter readings and temperature computed from the standard equation $T = (f - 1440)/36$ (where f is frequency in Hz, and T is temperature in ^{o}C) were listed on a HP9866B thermal printer. The reference (bath) temperature was provided by a HP 2801A quartz thermometer with $.001^{o}C$ resolution.*

* The HP5323A counter has an eight digit BCD output and a time base stability of 3 parts in 10^7/month. It was calibrated against a HP5016A Cesium Beam Frequency standard with time base reproducibility at National Bureau of Standards (NBS) of ± 5 parts in 10^{12}.

* The quartz thermometer was calibrated against an NBS certified platinum thermometer and an L & N voltage ratio bridge prior to and after each test. The platinum thermometer and ER bridge have a measurement uncertainty of $\pm .002^{o}C$.

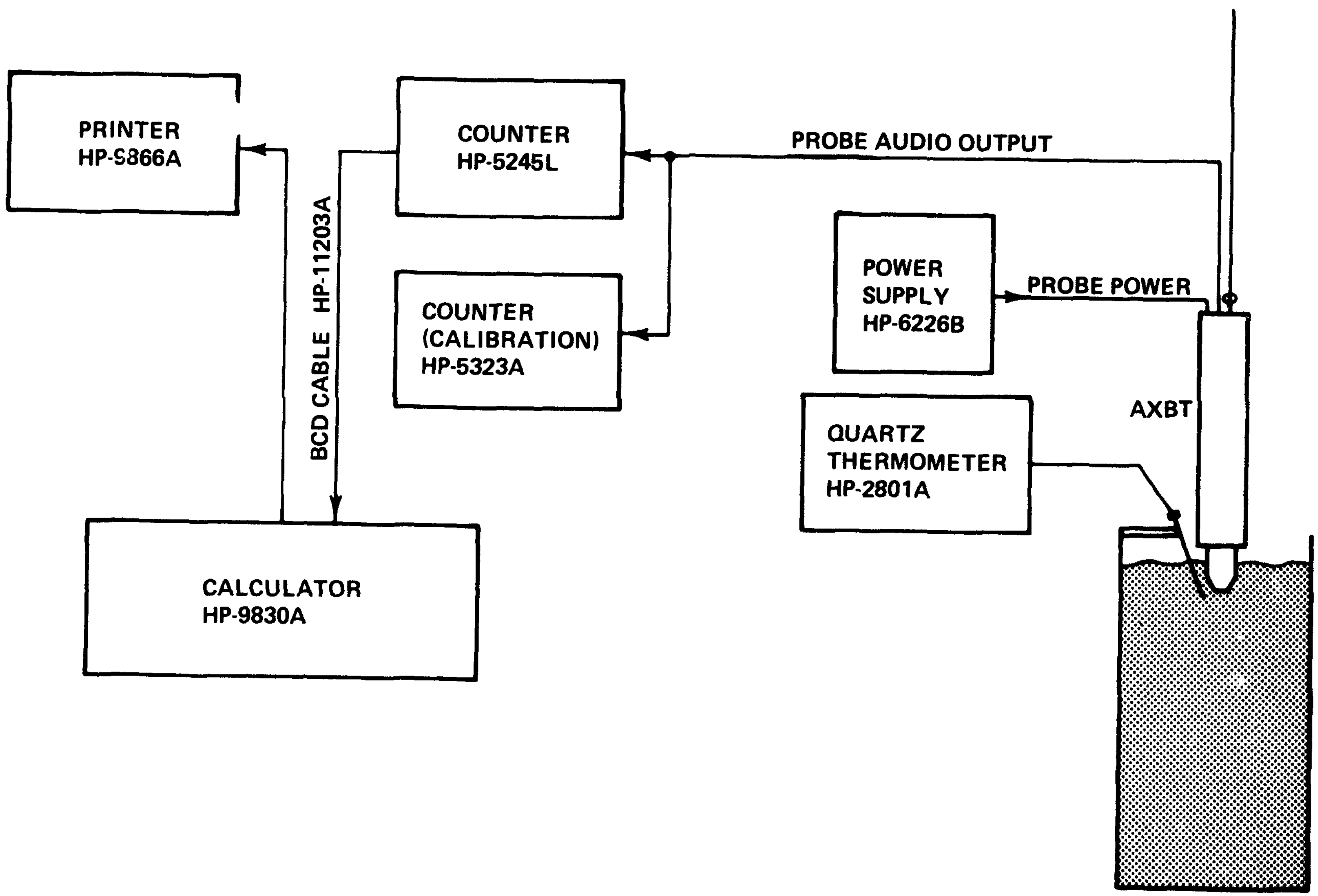


Figure 4 Hermes Test Configuration

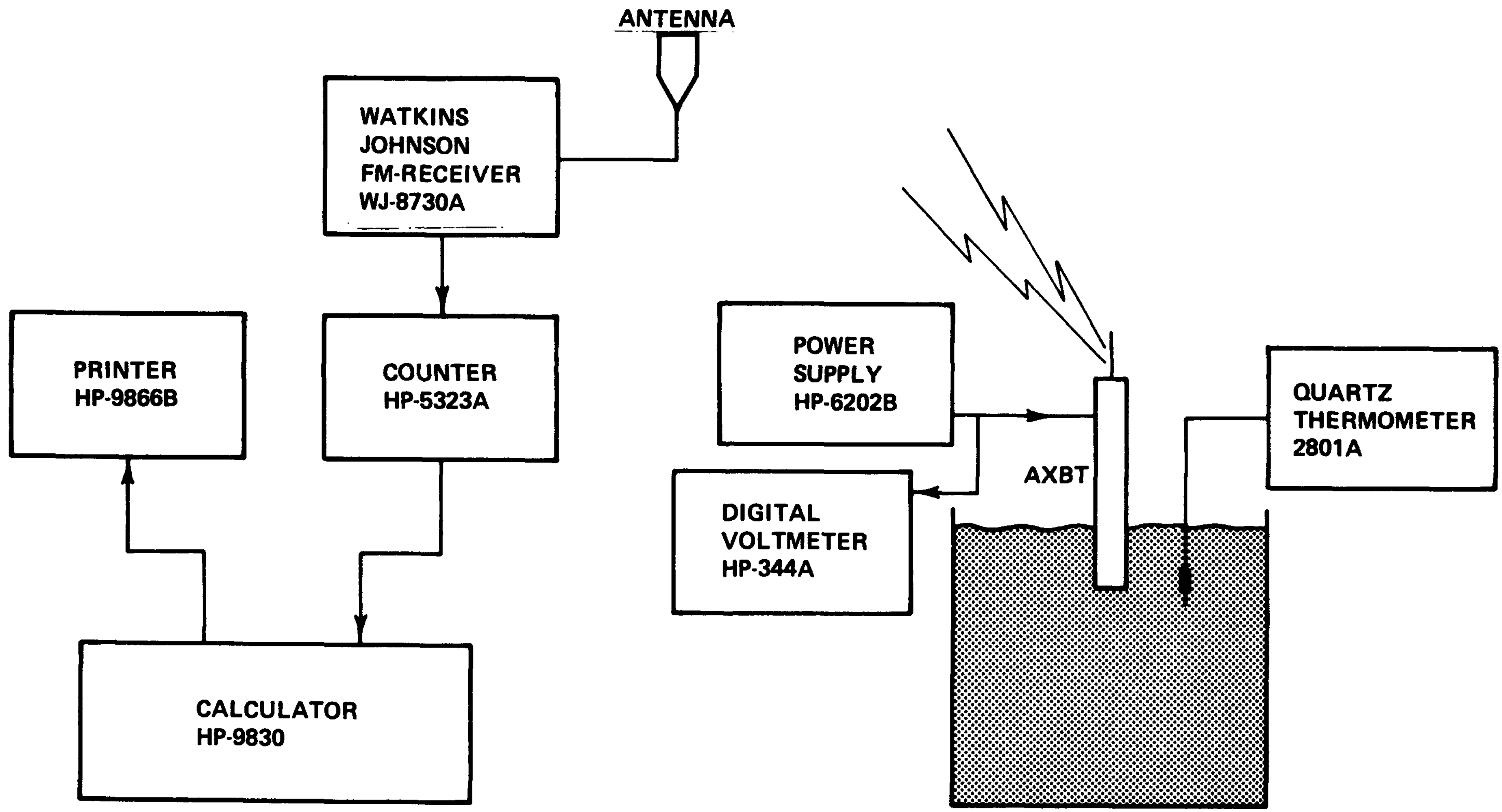


Figure 5 Sippican and Magnavox Test Configuration

Temperature Calibration

Preliminary testing was performed on the AXBTs to determine any supply voltage dependency or thermistor self-heating. A twelve-point temperature calibration was performed on several sensors randomly selected from each lot. Testing was conducted at 2,4,6,8,10,12,14,16,18,20,22,25°C. The remaining AXBTs were tested at 3 temperatures (5,15,25°C) or 4 temperatures (2,6,14,25°C). Initially tests were conducted with the 3 temperature settings, the change to 4 temperature settings was made to agree with the 12-point calibration data.

Hermes

The preliminary testing conducted on the Hermes units in March showed that no self heating was evident nor was there any noticeable supply voltage dependency. The calibration measurements were conducted with a supply voltage of +13VAC.

The twelve-point temperature calibration was performed on 4 units from Lot 45, 5 units from Lot 47, 9 units from Lot 39, and 9 units from Lot 43. Three measurements were made for each sensor at each of the 23 temperature points. The remaining AXBT tests in March (27 from Lot 45 and 20 from Lot 47) were conducted at temperatures of 5, 15 and 25°C while those tested in June (19 from Lot 39, 18 from Lot 43, and 9 from Lot 45) were conducted at 2, 6, 14 and 25°C.

Sippican

During the preliminary testing, it was discovered that due to the thermistor placement (figure 2C) there was insufficient bath stirring to prevent thermistor self heating. In order to overcome this problem a submersible pump was placed in the bath. Attached to the pump was a manifold which allowed 8 AXBTs to be attached for calibration. This flow calibration apparatus is shown in figure 6. Heating effects on the flow were considered negligible as both the manifold and pump were submerged in the bath. Graphs 1-4 indicate this test fixture significantly eliminated the self heating effects. Consequently this technique was used throughout the calibration tests.

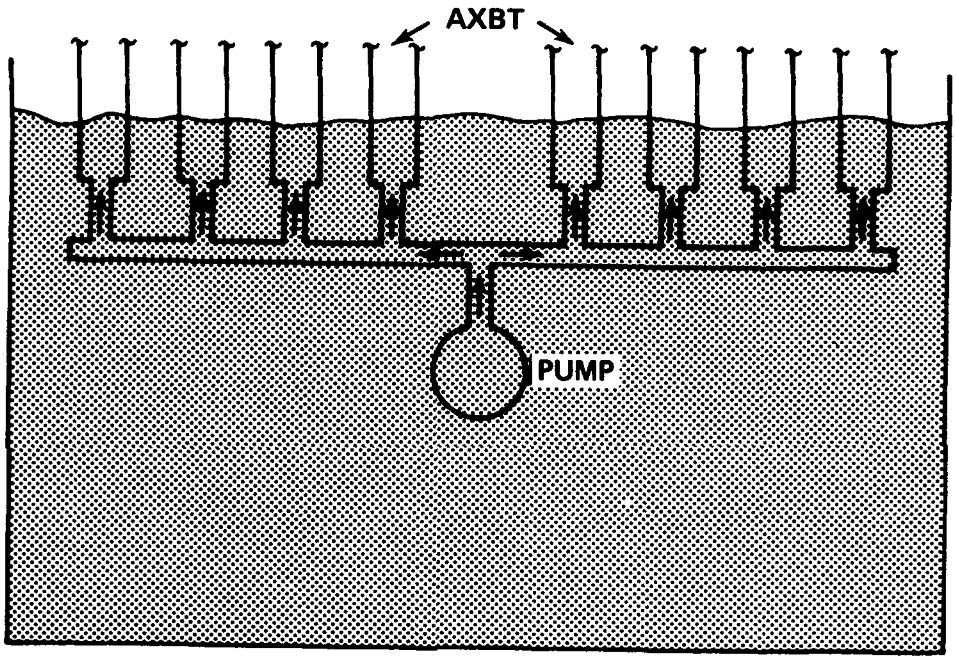
Pre-calibration testing also revealed output variation with changing supply voltage. This is shown in table 1. To maintain consistancy and comparability between the sensors, all subsequent testing was conducted with a reference supply voltage of +12VDC.

Eight units were selected at random from the 48 sensors on hand. A 12-point temperature was performed on these particular AXBTs. The remaining 40 units were calibrated at four temperature points (2,6,14,25°C). Twenty readings from each sensor were obtained at each temperature setting. The data was taken at a rate of 148 msec per sample.

Magnavox

Pre-calibration tests indicated no thermistor self heating when the AXBTs were placed in the bath. However, there was output variation with changes in supply voltage as shown in table 2. All subsequent testing was conducted with the external supply voltage set to +12VDC.

A total of 53 AXBTs were tested. Units were selected at random from each lot for the twelve temperature calibrations. These included: 3 each from Lots 1 and 11; 21 each from Lots 5 and 19 and 1 from Lot 7. The remaining units were checked at 2,6,14 and 25°C. Twenty readings were taken at each temperature setting at a rate of 148 msec per sample.



FLOW CALIBRATION APPARATUS

Figure 6 Sippican Calibration Apparatus

Calibration Test Results

Hermes

Using the sensor frequency obtained from the 2^oC incremental 12-point tests in comparison with the reference temperature (T_{ref}) provided by the quartz thermometer (tables 3-60)* the temperature error using the standard AXBT equation T_{std} (^oC) = (f-1440)/36 was examined for each lot where E_{std} (^oC)=T_{std}-T_{ref}. Lots 45, 47 and 43 indicated an average E_{std} ($\bar{E}_{std}$) greater than $+.5^oC$ for frequencies above 2250 Hz and for lot 39 above 2150 Hz.

Since the Standard equation yield $\bar{E}_{std}$ between $-.1^oC$ and $+.7^oC$ over the frequency range 1500 to 2350 Hz (2^oC - 25^oC), a third order polynomial relating output frequency to the reference temperature (T_{ref}) was fitted to the averaged 12-point data using the least squares method. The resultant temperature equation (NAVOCEANO Equation) yields $T_{NAV}(^oC) = C_0 + C_1f + C_2f^2 + C_3f^3$. The coefficients for each lot are as follows:

Lot	C_0	C_1	C_2	C_3	Standard Error of Estimate
45	-60.6684	.060118	$-.16417 \times 10^{-4}$	$.26787 \times 10^{-8}$	.003
47	-62.2449	.062670	$-.17769 \times 10^{-4}$	$.29173 \times 10^{-8}$	.004
43	-64.9371	.067131	$-.20142 \times 10^{-4}$	$.33236 \times 10^{-8}$	.009
39	-66.0341	.068776	$-.21027 \times 10^{-4}$	$.34775 \times 10^{-8}$	.010

The average error using the NAVOCEANO equation ($\bar{E}_{NAV}$) for the 12-point data is significantly less than $\bar{E}_{std}$ as summarized below:

	$\bar{E}_{NAV}$	$\bar{E}_{NAV}$ Max	$\bar{E}_{std}$	$\bar{E}_{std}$ Max
Lot	Range (^oC)	STD Dev.	Range (^oC)	STD Dev.
45	-.009 to .005	.091	-.032 to .574	.091
47	-.003 to .011	.072	-.059 to .524	.072
43	-.013 to .017	.116	-.102 to .569	.112
39	-.021 to .017	.164	.011 to .687	.164

Graphs 5 - 8 show the average error comparison between the standard and NAVOCEANO equations. Also indicated on these graphs is the average error from the remaining AXBTs in each lot from the 3-temperature and 4-temperature data points.

* Tables 3-60 are not in this report but are available upon request.

A summary of the temperature error for this data is shown below.

Lot	$\bar{E}_{NAV}$ Range (^oC)	Max STD Dev.	$\bar{E}_{std}$ Range (^oC)	Max STD Dev.
45	-.001 to .024	.086	-.021 to .562	.113
47	-.104 to .004	.232	-.046 to .416	.230
43	-.057 to .024	.113	-.081 to .501	.114
39	-.047 to .042	.152	.053 to .633	.152

Actual data plots of the information summarized above are presented in graphs 16-33. During the testing, sensors 15(lot 43) and 19(lot 45) failed after several measurements. Sensor 30(lot 47) did not operate at all. Fifty three AXBTs were reassembled and forwarded for field deployment.

Sippican

The calibration data obtained for the Sippican AXBTs is presented in tables 61-74. Of the 9 sensors used in performing the 12-temperature point tests only one produced a temperature error in excess of +.5^oC when the standard AXBT equation was used. The average error $\bar{E}_{std}$ for the standard equation ranged from -.165 to .319^oC with a maximum standard deviation of 0.145. A third order least squares curve fit was performed on the averaged 12-point data. This produced the equation $T_{NAV} = -66.8857 + .070273f - .21807 \times 10^{-4} f^2 + .36311 \times 10^{-8} f^3$ with a standard error of estimate equal 0.012.

The average error $\bar{E}_{NAV}$ for the NAVOCEANO equation ranged from -.020^oC to .022^oC with a maximum standard deviation of .154 for the 12-point data. A comparison of the average error obtained from using the standard and NAVOCEANO equations is shown in graph 9. Also on this graph is a plot of the average error from the 4-point temperature checks on 37 sensors. There is very good agreement between the 12-point and 4-point error averages with errors ranging from .009^oC to .050^oC for $\bar{E}_{NAV}$ with a maximum standard deviation of .075. Graphs 34-37 depict the actual temperature error measured for each sensor for both equations at the 12-point and 4-point temperature calibrations.

Three of the 43 units tested suffered electronic failures (#1, 2 and 288), and sensor 356 produced spurious outputs at 2^oC. In all, 39 sensors were reassembled and shipped for deployment.

Magnavox

The test data from the Magnavox units are presented in tables 75-135. There is considerable lot-to-lot variation in the average error $\bar{E}_{std}$ derived from the standard AXBT equation. There is, however, a general trend in that all lots, with exception of lot 1, exhibit average temperature errors greater than -.5^oC for frequencies below 1850Hz (11^oC). This large negative error is also different from the general trends exhibited by the Hermes and Sippican units.

Using a least squares curve fit routine to model the data, a third order polynomial $T_{NAV} = C_0 + C_1 f + C_2 f^2 + C_3 f^3$ was derived for each lot. These coefficients are listed as follows:

Lot	C_0	C_1	C_2	C_3	Standard error of estimate
1	-47.1819	.040980	$-.72939 \times 10^{-4}$	$.12362 \times 10^{-8}$	.032
5	-65.9632	.070036	$-.21912 \times 10^{-4}$	$.36505 \times 10^{-8}$	.019
7	-64.7019	.068215	$-.20901 \times 10^{-4}$	$.34628 \times 10^{-8}$	.048
11	-60.9306	.061516	$-.17116 \times 10^{-4}$	$.27827 \times 10^{-8}$	.030
19	-54.3513	.051613	$-.11965 \times 10^{-4}$	$.18687 \times 10^{-8}$	.034
21	-51.5242	.046827	$-.94730 \times 10^{-4}$	$.14478 \times 10^{-8}$	.040

As seen from the standard error of estimate column in the coefficient table above, the curve fits for the Magnavox AXBT lots are not as precise as those of the Sippican and Hermes previously noted. This is due to the large data scatter measured at the lower test temperatures and the small number of sensors tested from each lot. A comparison of the standard and NAVOCEANO equation using the averaged data is shown in graphs 10-15 for each lot and is summarized below for the 12-point data:

Lot	$\bar{T}_{NAV}$ (°C) range	Maximum std. dev.	$\bar{T}_{std}$ (°C) range	Maximum std. dev.
1	-.053 to .055	.187	-.401 to .404	.194
5	-.028 to .026	.258	-.524 to .295	.268
7	-.070 to .100	-	-.736 to .200	-
11	-.070 to .059	.263	-.672 to .046	.270
19	.005 to .095	.157	-.814 to -.092	.167
21	-.034 to .058	.147	-.651 to .263	.153

The 4-point temperature data are also depicted in graphs 10-15 for each lot. While these error averages deviate from those from the 12-point temperature data at the lower frequencies, the errors do, however, fall within the standard deviations computed for the 12-point error averages. Graphs 38-53 show the temperature errors for each sensor at each test temperature. Again note the large error scatter. While most of the AXBTs tested produced temperature errors exceeding the -.5°C specification, there were no sensor failures noted.

Thermal Time Constant

The thermal time constant tests were conducted using the automatic test systems shown earlier in figures 4 and 5. Data were read from an HP532A counter by an HP9830 calculator at a rate of 58 msec/sample. Prior to testing, the response of the probe circuitry was determined to be instantaneous using a decade resistance to simulate the thermistor. A thermal time constant is defined as the time required for the sensor to respond to 63.2% of step change in temperature. The thermal time constant test procedures used here are not considered optimal. It is felt that useful information regarding relative response times have been generated and that approximations of the real time constraints of the sensors have been measured. The use of these data for filter design is not recommended.

Hermes

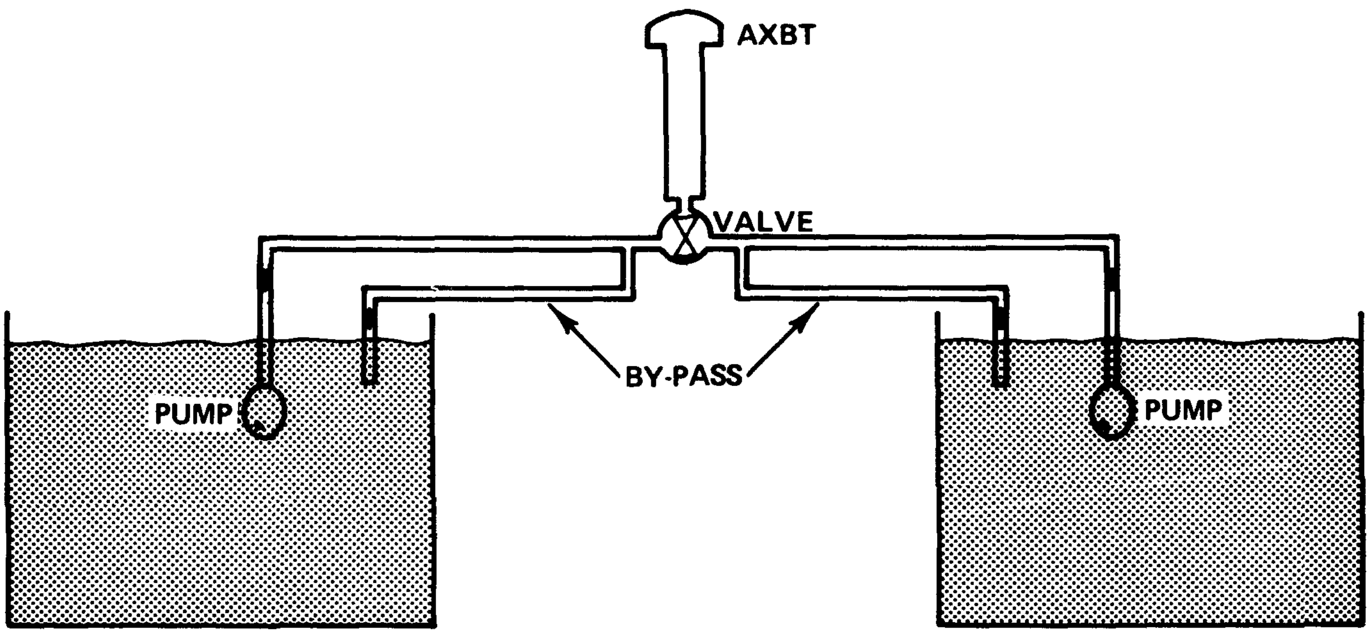
The Hermes AXBTs were tested using a rope-pulley arrangement to drop the units from air at room temperature into a stable bath. In order to determine the thermistor response, the protective plate covering the thermistor (figure 1C) was removed. While this was not the normal operating configuration of the probe, it did provide data about the unrestricted response of the thermistor when encountering a step change in temperature. Because of the decrease in flow restriction caused by plate removal and because of the air/water test procedure, data collected is thought to be "best case" or show a shorter time constant that would be encountered in-situ.

Sippican

Because of thermistor self heating, as noted earlier, an air-water drop to determine time response was considered to be impractical. After consideration, the test apparatus shown in figure 7 was developed as the simplest alternative. This "drop test" apparatus operated by pumping water to a three port valve from two baths at different temperatures. A bypass line was included at the input ports of the valve to continually recycle water to maintain a stable temperature at the unused port. An HP9830 calculator read the AXBT output from a frequency counter at a rate of 58 msec/sample. After several readings were taken with one flow temperature the valve was switched to the other flow. This provided the step change in temperature in determining the thermistor time response. While this test gives a good indication as to the sensor's time response, it does not provide the precision that elaborate laboratory apparatus or actual field deployment would provide.

Magnavox

Time response testing on the Magnavox units was conducted in a similar manner to the Hermes AXBTs. An air-water drop was made using a rope pulley arrangement. The Magnavox AXBTs do not have a protective cover shielding their thermistors.



"DROP TEST" APPARATUS

Figure 7

Time Response Results

Hermes

Time response tests were performed upon randomly selected units from each lot on hand. Of the units tested 4 were from lot 45, 5 from lot 47, 3 each from lots 39 and 43. The time constant tests performed on lots 45 and 47 in March included drops from air to water at 15°C and 5°C. As shown in table 136 there is no significant difference in response for either step change. Based on the March tests, the units from lots 43 and 39 were dropped into a bath at 12°C. These results are listed in table 135. Three drops were performed on each sensor. The lag value in meters was computed as follows:

Lag (m) = Time Response (sec) x Drop Rate (m/sec)

where Time response = 5 x Time Constant

Drop rate = 1.52 m/sec.

The average time response and lag for each lot are listed below:

Lot	Time Response (sec)	Lag (m)
45	1.263	1.92
47	1.385	2.11
43	.946	1.44
39	.846	1.29

As stated earlier, these measurements were obtained with the thermistor's protective cover removed which would be close to the ideal case for fastest possible response time even when considering an air water interface. Since the plate is present as the probe descends in-situ, a greater thermal lag should be present during actual deployment.

Sippican

Time response testing was conducted on 8 Sippican AXBTs selected at random from the test group. Three tests were conducted on each sensor with one bath at 25°C and the other at 10°C. The results are listed in table 137 which summarized shows an average time response of .917 sec corresponding to a thermal lag of 1.39m.

Magnavox

Due to time constraints only 6 Magnavox AXBTs were tested for time response with one unit coming from each lot. The results are listed below:

Lot	S.N.	Time Response (sec) @14°C	Lag (m) @14°C	Time Response (sec) @4°C	Lag (m) @4°C
1	75	3.258	4.94	4.132	6.28
5	4962	2.465	3.75	2.725	4.14
7	7356	2.610	3.97	3.000	4.56
11	11654	3.100	4.71	3.130	4.76
19	20176	3.045	4.63	4.843	7.36
21	23011	3.132	4.76	2.725	4.14

The measured time response is significantly greater than that for either the Hermes or Sippican AXBTs. Except in the case of sensor 23011 from Lot 21, the time response was greater for drops in the 4°C bath than for the 14°C bath. Precision resistors were substituted in place of the thermistors in one unit to determine if the increased response was due to temperature sensitivity in the probe electronics. No such dependency was evident. The large time response may be due to a rather thick coating on the thermistors used in the Magnavox AXBTs.

Conclusions

Temperature Accuracy

The calibration of the AXBTs demonstrates the variability of temperature characteristics between the various manufacturers, Hermes, Sippican and Magnavox and between lots produced by each manufacturer. The Sippican units exhibited the best temperature calibration using the standard AXBT equation with average temperature errors below the $\pm.5^{o}C$ specifications. Both the Hermes and Magnavox groups showed average errors exceeding the specifications with the Hermes exhibiting average errors greater than $+.5^{o}C$ at high temperature and the Magnavox greater than $-.5^{o}C$ at low temperature. By applying the NAVOCEANO curve fit equations for each manufacturer's lot the temperature error should readily meet the $\pm.5^{o}C$ specification. In most cases the error will fall within $\pm.3^{o}C$.

Time Response

The Hermes and Sippican AXBTs exhibited the best temperature response in the presence of a step change in temperature with time constants on the order of 200 msec. The Magnavox units showed time constants approximately 3 times those of the Sippican and Hermes AXBTs. This, it is believed, is due to the thickness of the thermistor coating.

Errata

The Sippican Corporation in its technical newsletter "Horizon" Volume 5, No. 1 1980 presented a temperature equation for the Sippican AXBT probe.* The expression is as follows:

$$T(^{o}C) = C_0 + C_1 f + C_2 f^2 + C_3 f^3 + C_4 f^4 + C_5 f^5$$

where

$C_0 = -126.662$

$C_1 = .219954$

$C_2 = -1.705096 \times 10^{-4}$

$C_3 = 7.70534 \times 10^{-8}$

$C_4 = -1.7958 \times 10^{-11}$

$C_5 = 1.73823 \times 10^{-15}$

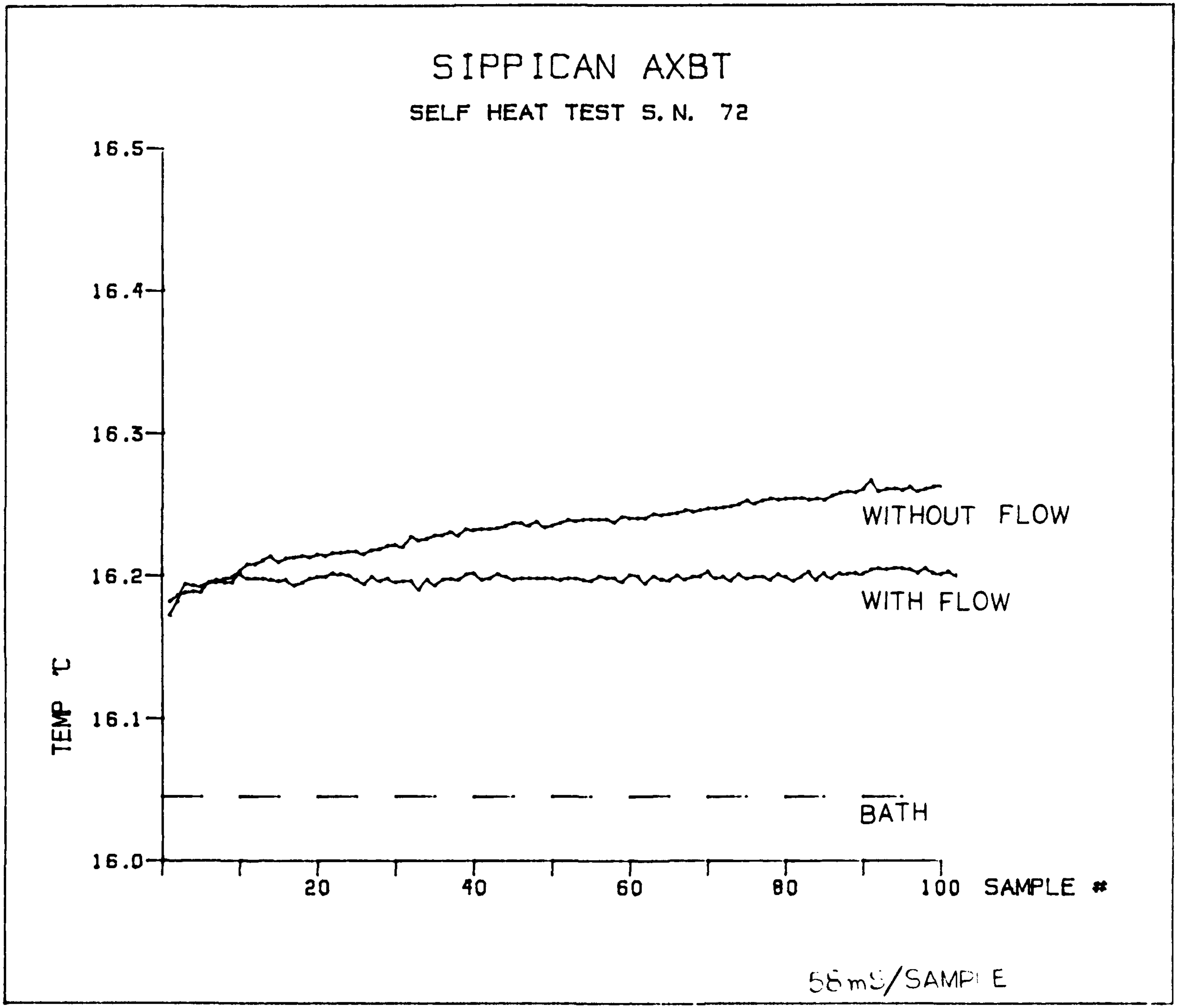
Substituting the test data for the Sippican AXBT measurements, showed the temperature error plotted in graph 54. For the test data this equation produced temperature errors exceeding $+.5^{o}C$. Adjusting the C_0 parameter to equal -127.0505 this equation can be adjusted with average temperature errors between $\pm .2^{o}C$.

(*) Alan T. Hudson, "Aircraft Launched XBT Development", Horizon, Vol. 5 (Marion, Massachusetts; The Sippican Corporation, 1980) p.2.

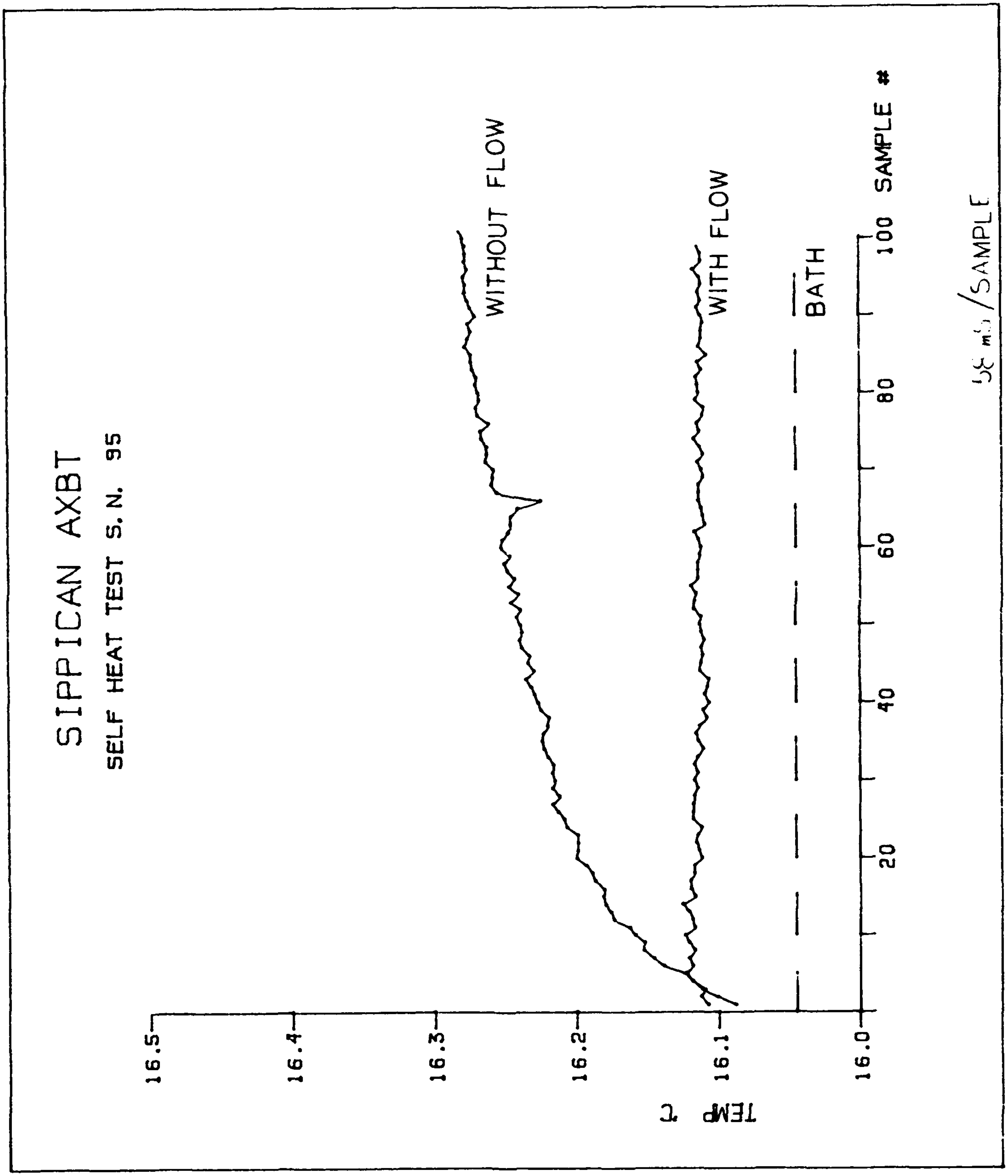
APPENDIX A

GRAPHS

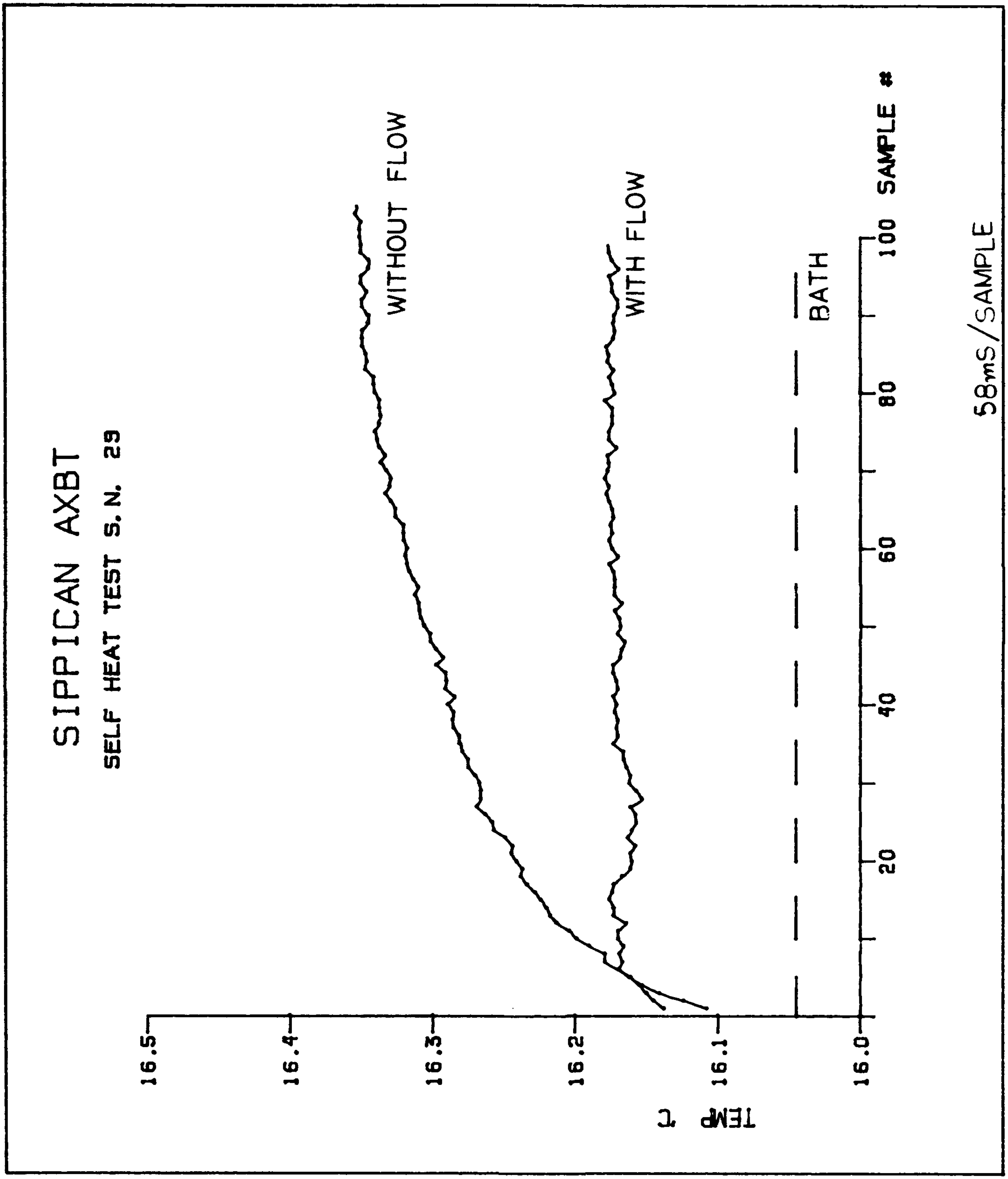
GRAPHS


SIPPICAN AXBT
SELF HEAT TEST S. N. 72
16.5
16.4
16.3
16.2
16.1
16.0
TEMP °C
WITHOUT FLOW
WITH FLOW
BATH
20
40
60
80
100
SAMPLE #
58mS/SAMPLE

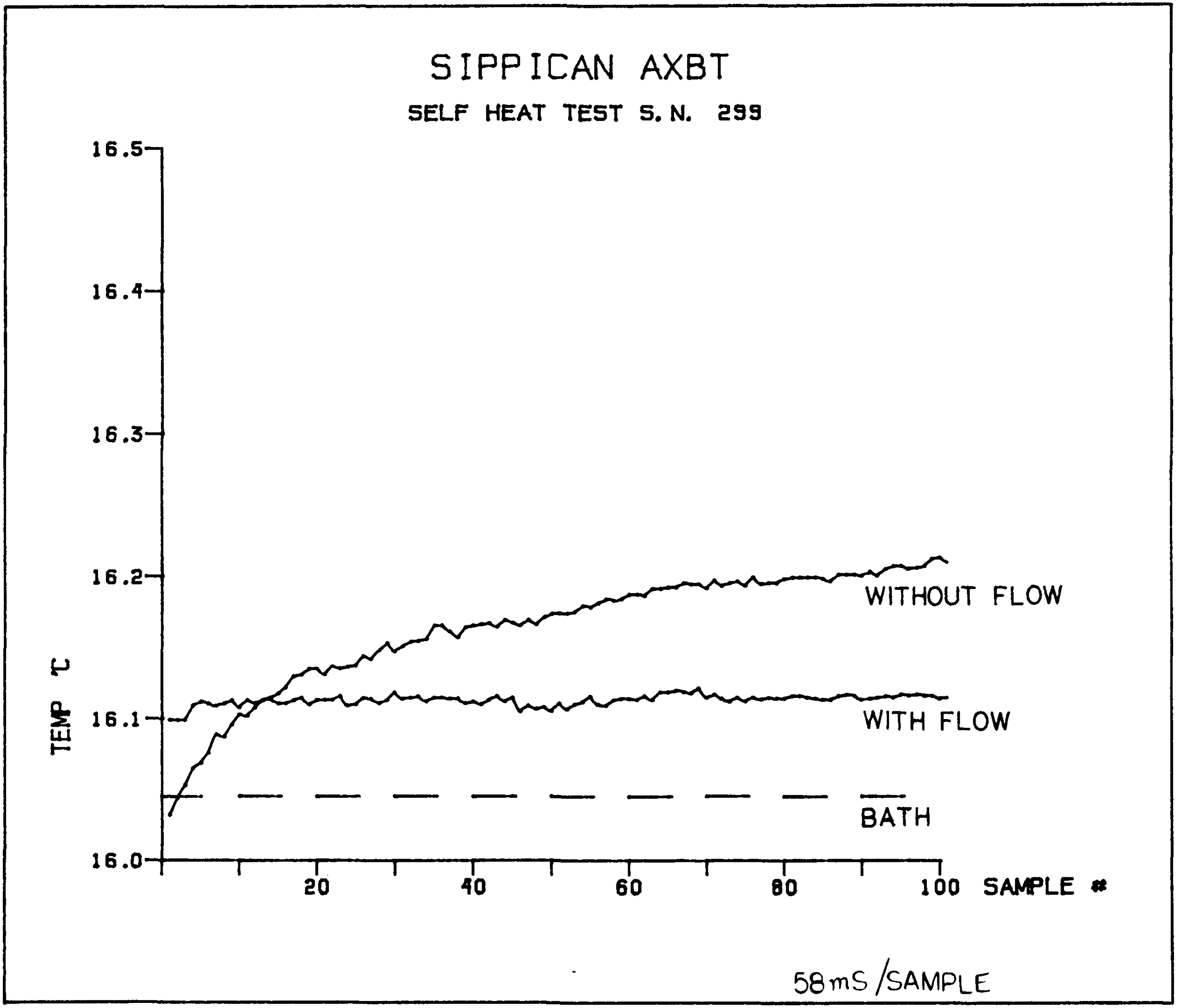
GRAPH 1


SIPPICAN AXBT
SELF HEAT TEST S.N. 95
WITHOUT FLOW
WITH FLOW
BATH
SAMPLE #
20
40
60
80
100
16.0
16.1
16.2
16.3
16.4
16.5
TEMP °C

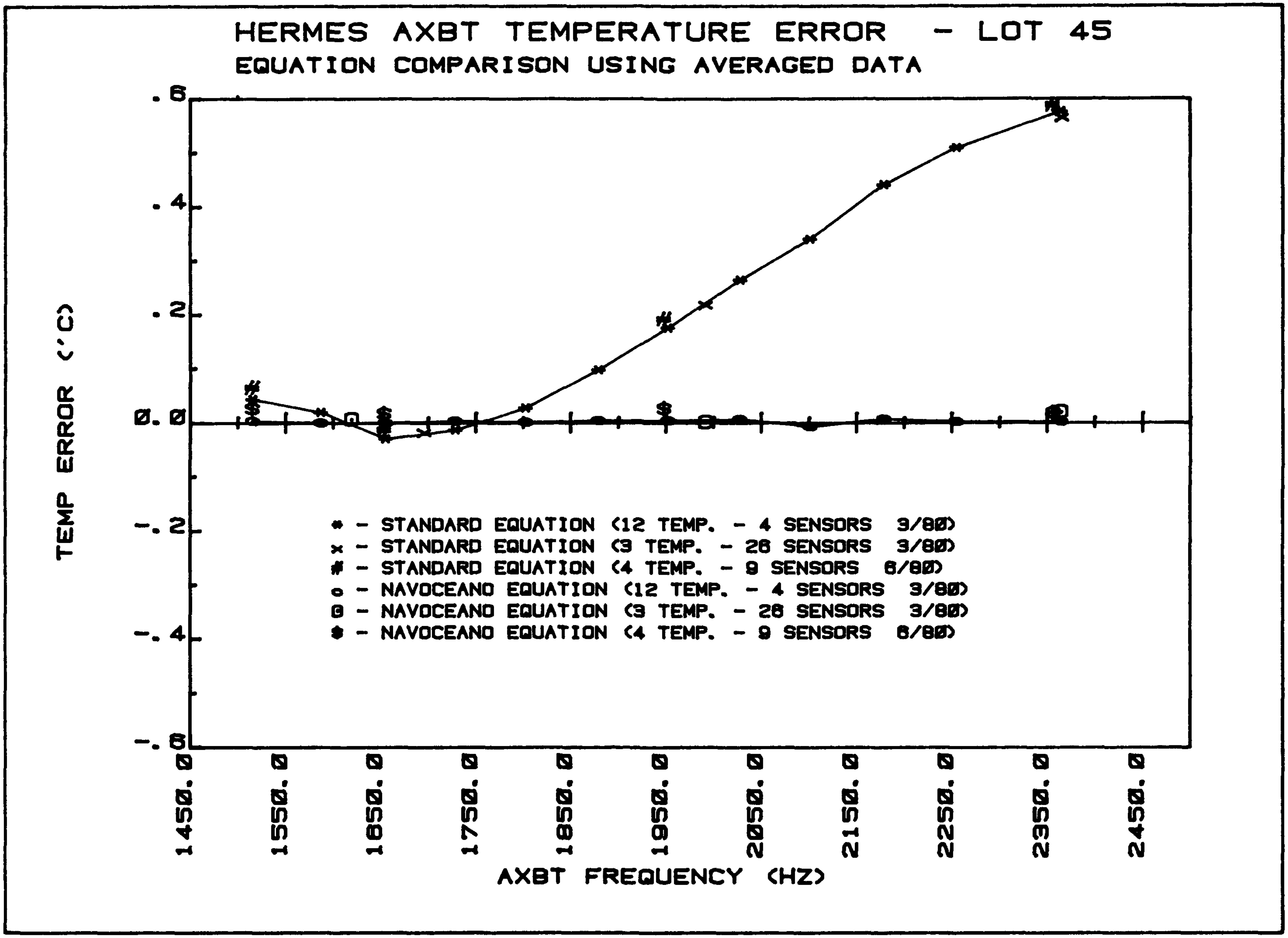
GRAPH 2


SIPPICAN AXBT
SELF HEAT TEST S.N. 29
WITHOUT FLOW
WITH FLOW
BATH
TEMP °C
16.0
16.1
16.2
16.3
16.4
16.5
20
40
60
80
100
SAMPLE #
58mS/SAMPLE

GRAPH 3

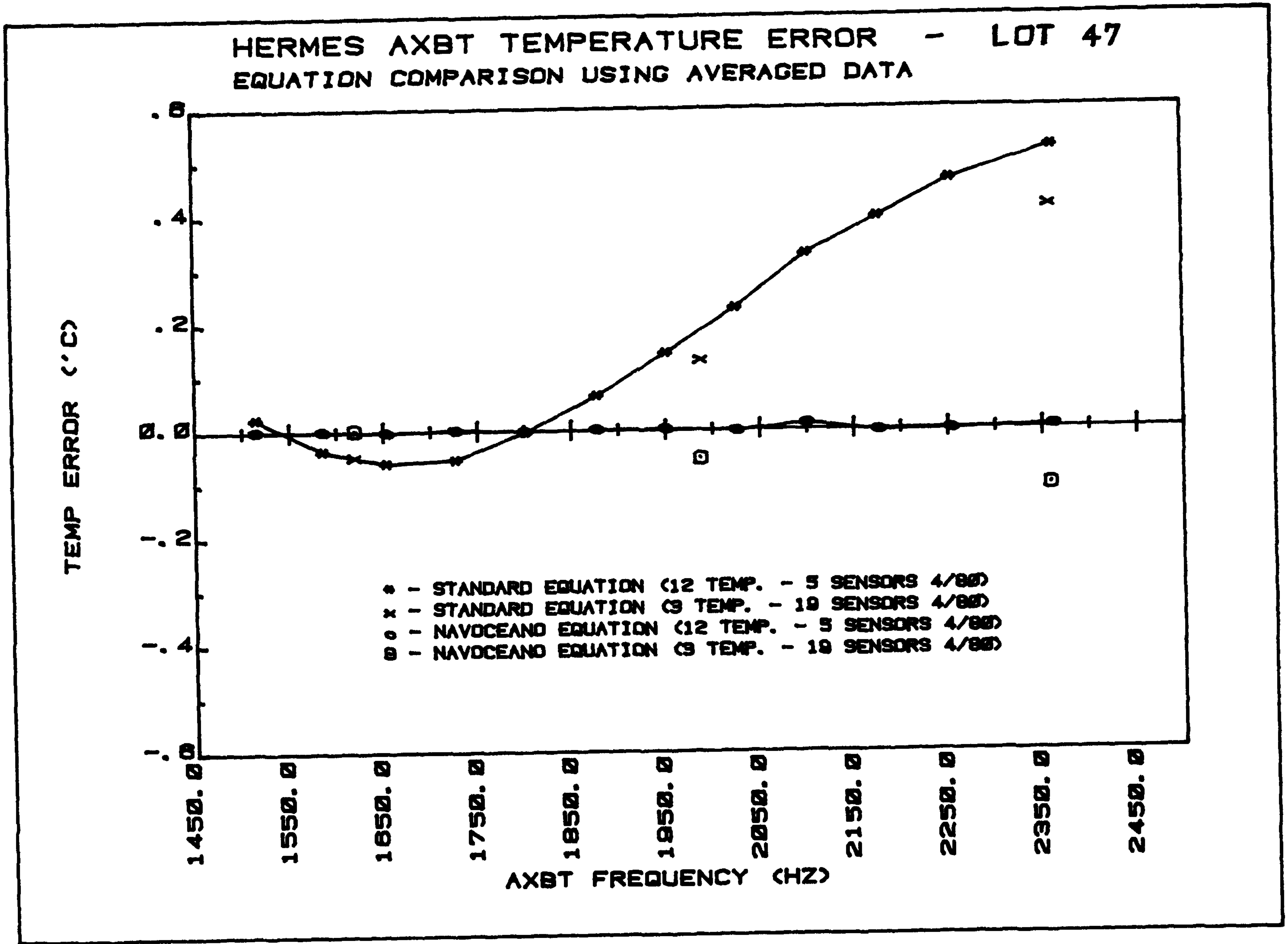

SIPPICAN AXBT
SELF HEAT TEST S.N. 299
TEMP °C
16.5
16.4
16.3
16.2
16.1
16.0
20
40
60
80
100
SAMPLE #
WITHOUT FLOW
WITH FLOW
BATH
58mS/SAMPLE

GRAPH 4

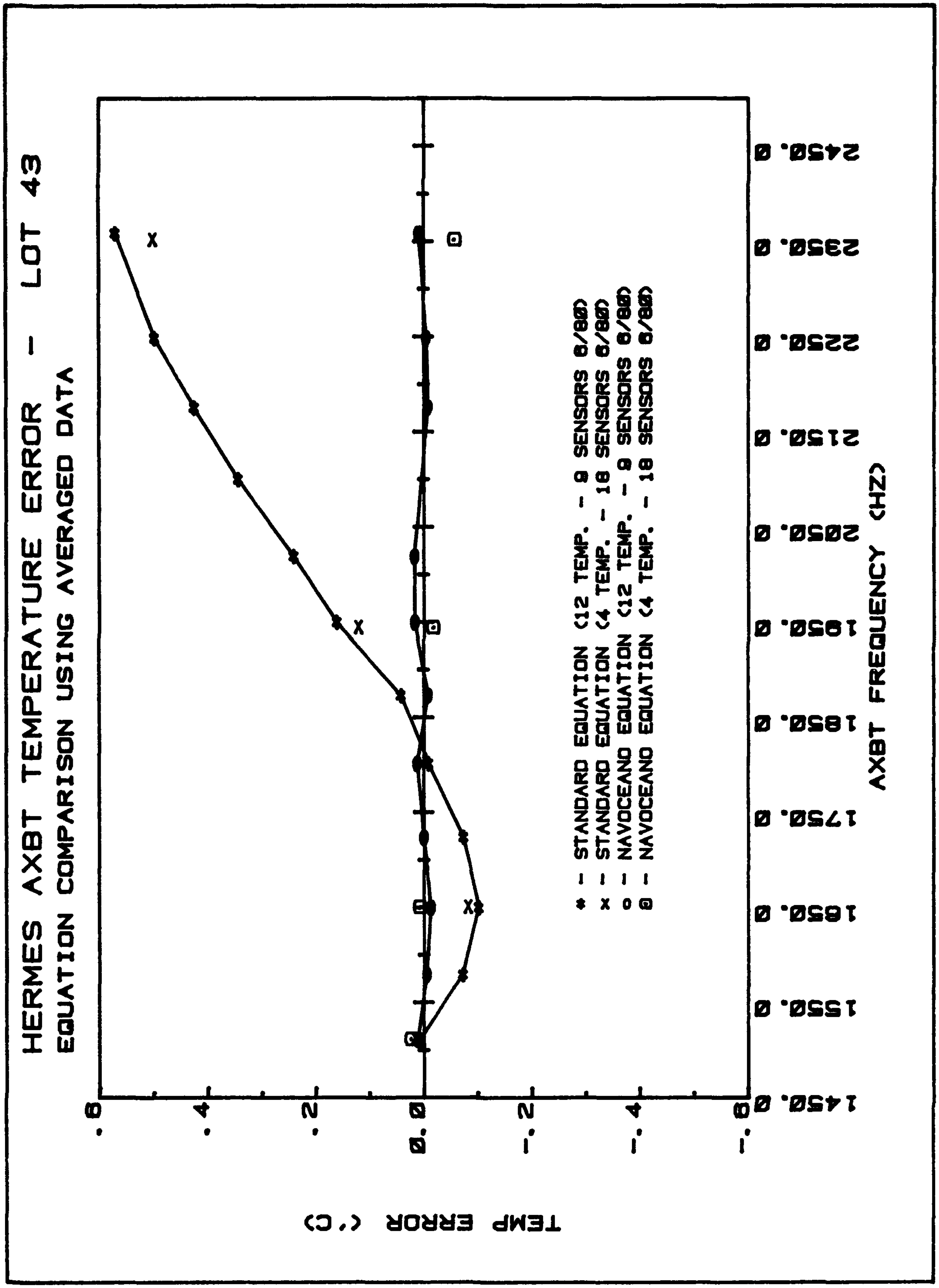


HERMES AXBT TEMPERATURE ERROR - LOT 45
EQUATION COMPARISON USING AVERAGED DATA
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)
* - STANDARD EQUATION (12 TEMP. - 4 SENSORS 3/80)
x - STANDARD EQUATION (3 TEMP. - 26 SENSORS 3/80)
- STANDARD EQUATION (4 TEMP. - 9 SENSORS 6/80)
o - NAVOCEANO EQUATION (12 TEMP. - 4 SENSORS 3/80)
G - NAVOCEANO EQUATION (3 TEMP. - 26 SENSORS 3/80)
$ - NAVOCEANO EQUATION (4 TEMP. - 9 SENSORS 6/80)

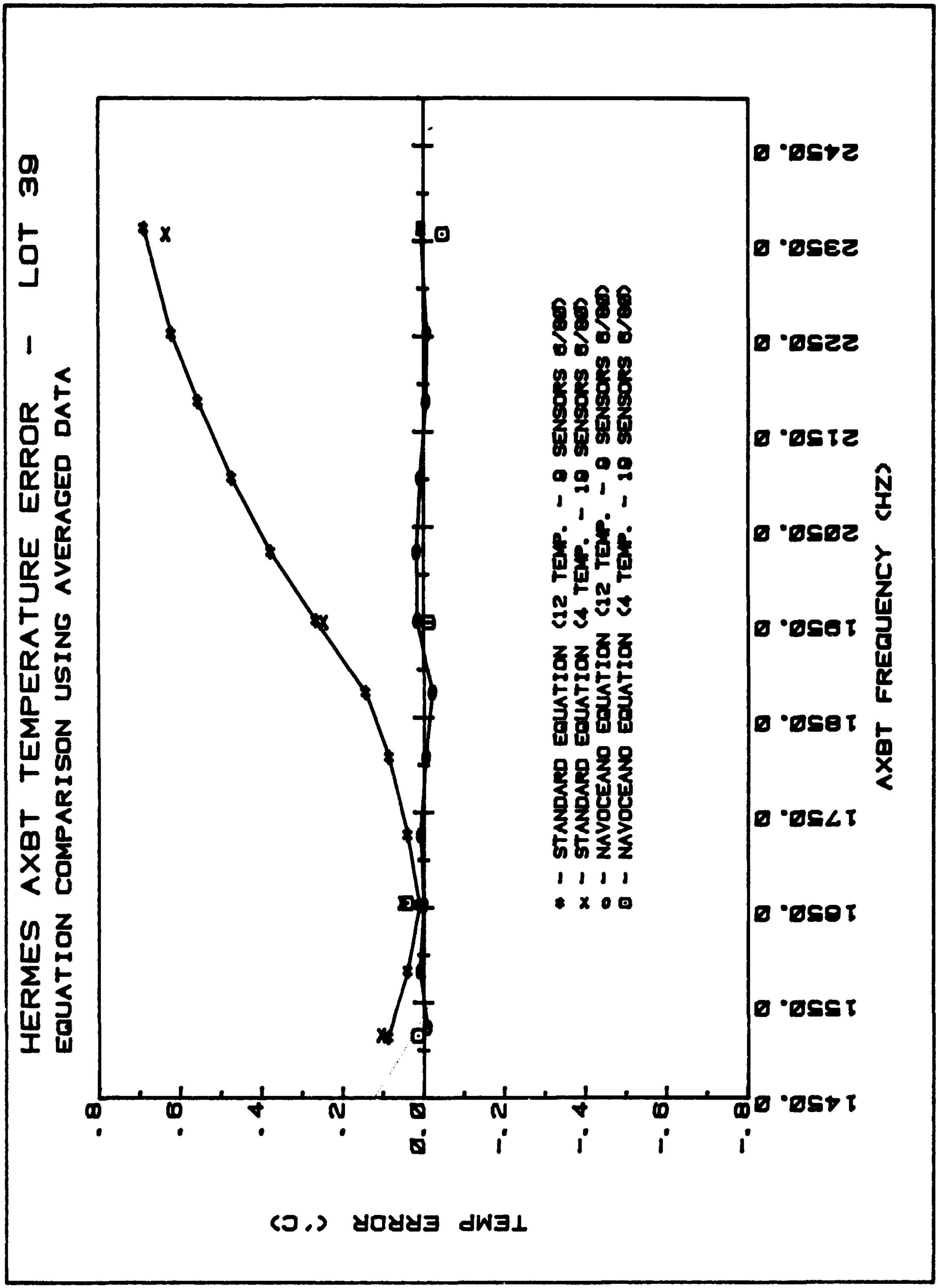
GRAPH 5


HERMES AXBT TEMPERATURE ERROR - LOT 47
EQUATION COMPARISON USING AVERAGED DATA
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)
* - STANDARD EQUATION (12 TEMP. - 5 SENSORS 4/80)
x - STANDARD EQUATION (3 TEMP. - 10 SENSORS 4/80)
o - NAVOCEANO EQUATION (12 TEMP. - 5 SENSORS 4/80)
8 - NAVOCEANO EQUATION (3 TEMP. - 10 SENSORS 4/80)

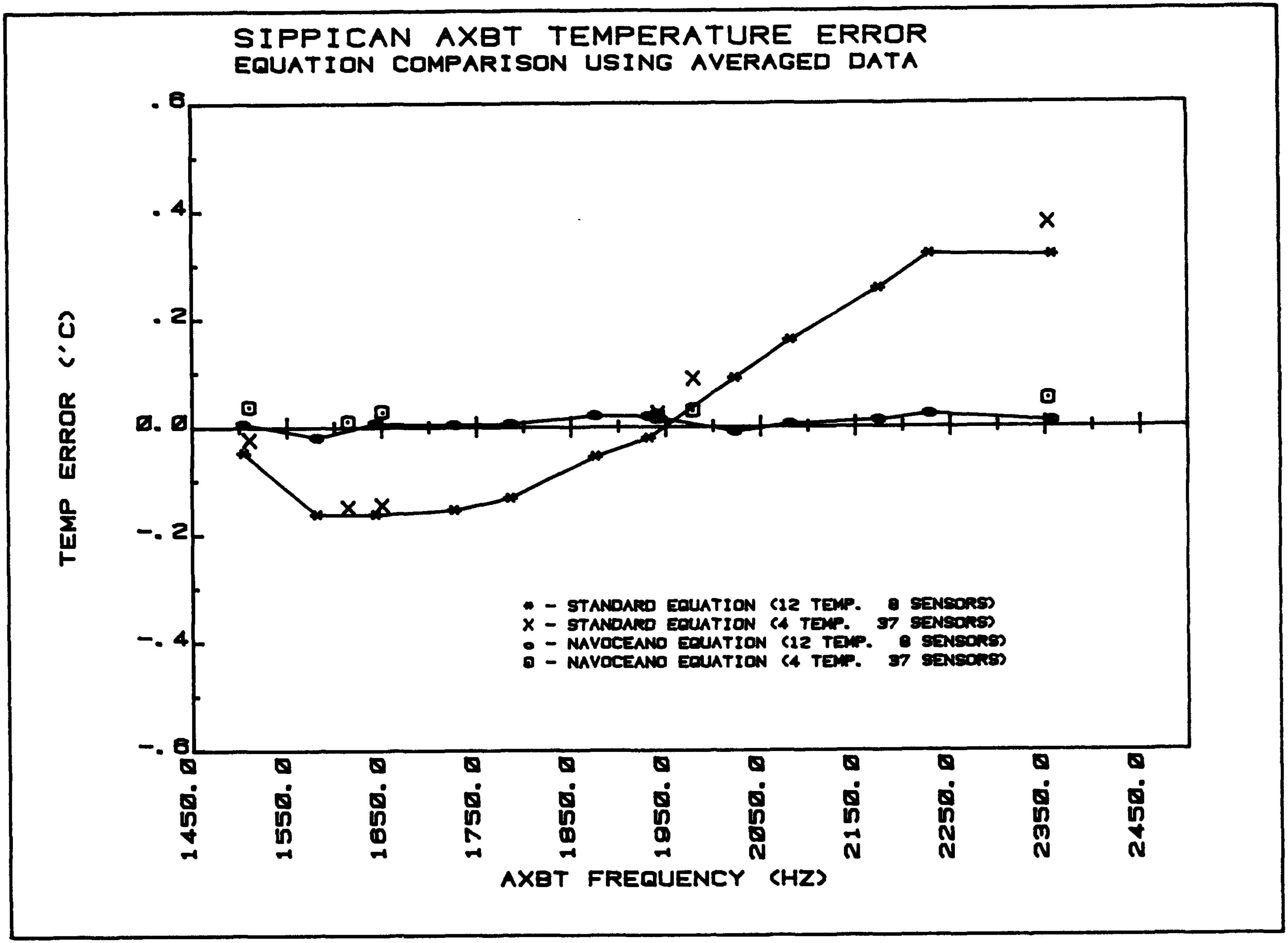
GRAPH 6


HERMES AXBT TEMPERATURE ERROR - LOT 43
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 9 SENSORS 6/80)
x - STANDARD EQUATION (4 TEMP. - 18 SENSORS 6/80)
o - NAVOCEANO EQUATION (12 TEMP. - 9 SENSORS 6/80)
⊡ - NAVOCEANO EQUATION (4 TEMP. - 18 SENSORS 6/80)
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 7

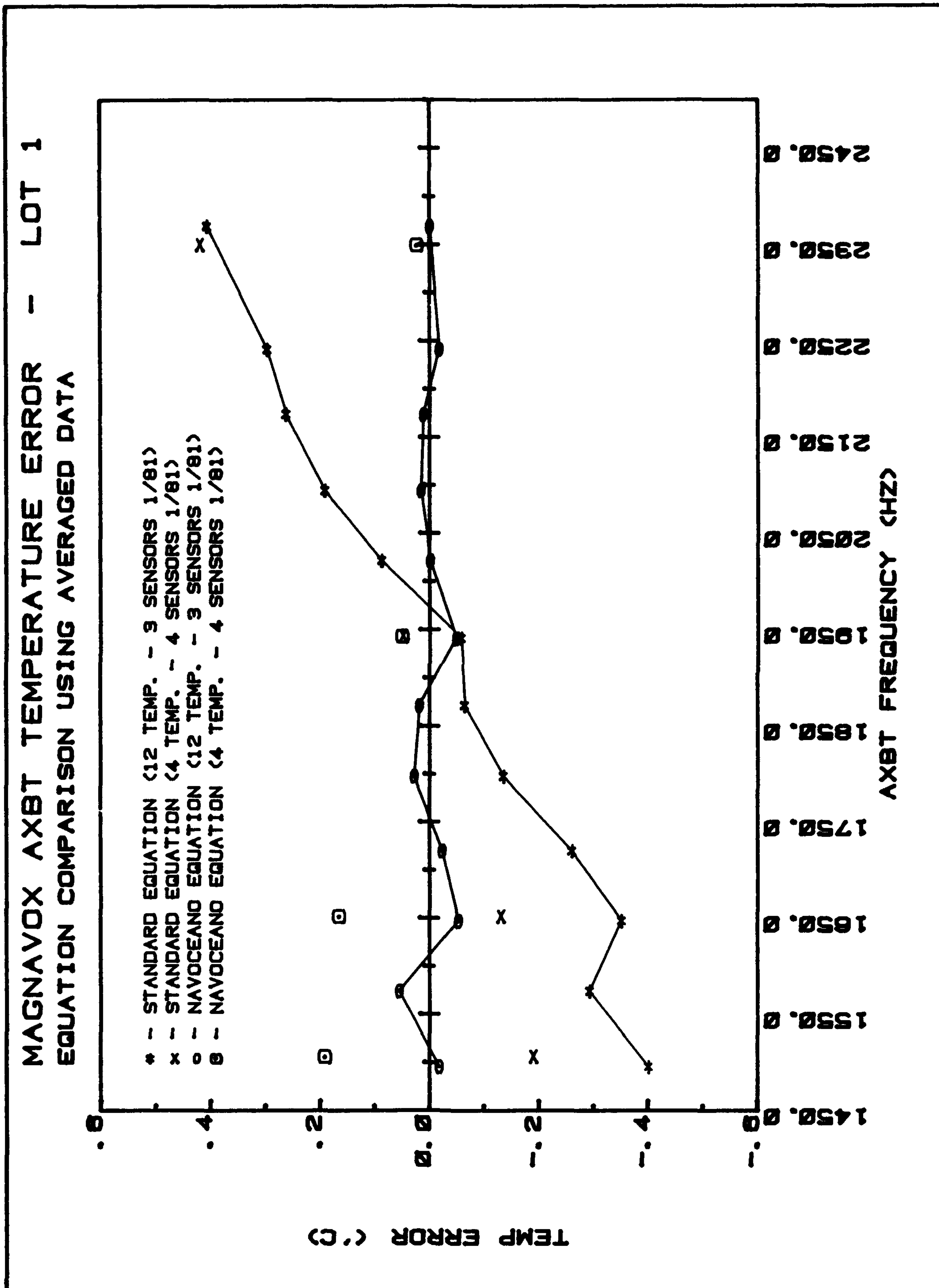

HERMES AXBT TEMPERATURE ERROR - LOT 39
EQUATION COMPARISON USING AVERAGED DATA
TEMP ERROR ('C)
AXBT FREQUENCY (HZ)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
* - STANDARD EQUATION (12 TEMP. - 0 SENSORS 6/90)
X - STANDARD EQUATION (4 TEMP. - 10 SENSORS 6/90)
o - NAVOCEANO EQUATION (12 TEMP. - 0 SENSORS 6/90)
□ - NAVOCEANO EQUATION (4 TEMP. - 10 SENSORS 6/90)

GRAPH 8

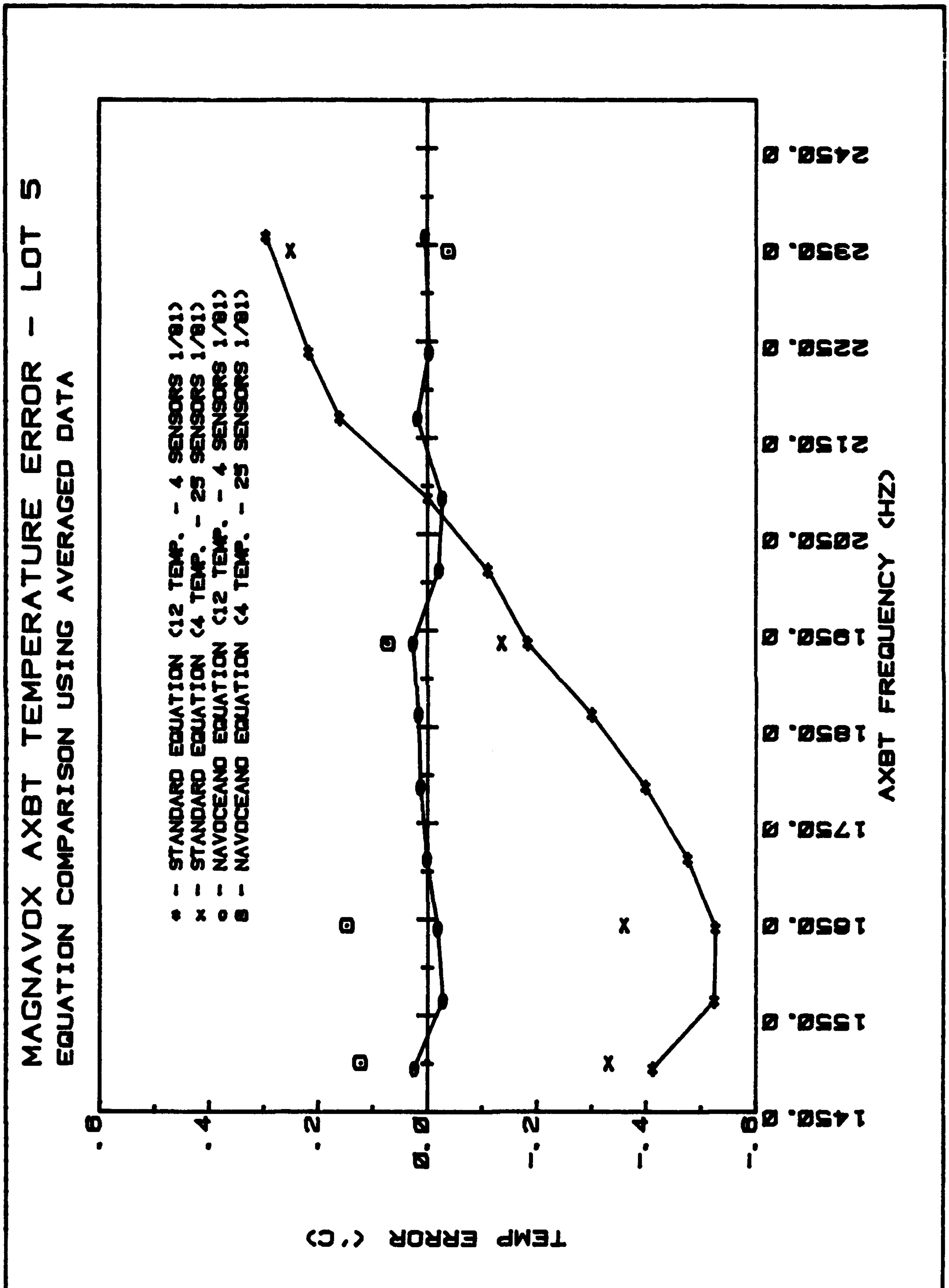


SIPPICAN AXBT TEMPERATURE ERROR
EQUATION COMPARISON USING AVERAGED DATA
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)
* - STANDARD EQUATION (12 TEMP. 8 SENSORS)
X - STANDARD EQUATION (4 TEMP. 37 SENSORS)
o - NAVOCEANO EQUATION (12 TEMP. 8 SENSORS)
□ - NAVOCEANO EQUATION (4 TEMP. 37 SENSORS)

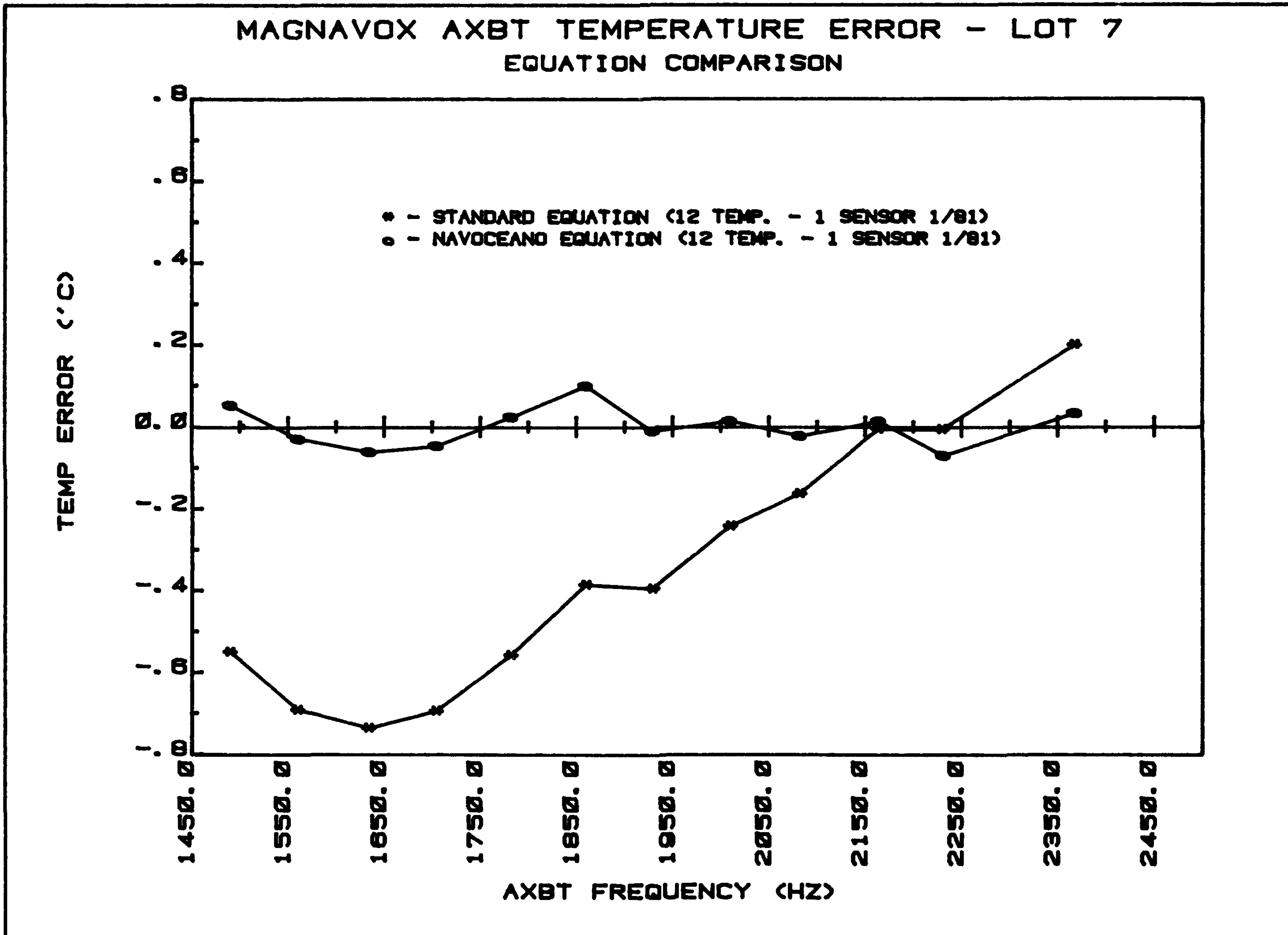
GRAPH 9


MAGNAVOX AXBT TEMPERATURE ERROR - LOT 1
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 3 SENSORS 1/81)
X - STANDARD EQUATION (4 TEMP. - 4 SENSORS 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 3 SENSORS 1/81)
⊡ - NAVOCEANO EQUATION (4 TEMP. - 4 SENSORS 1/81)
TEMP ERROR (°C)
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

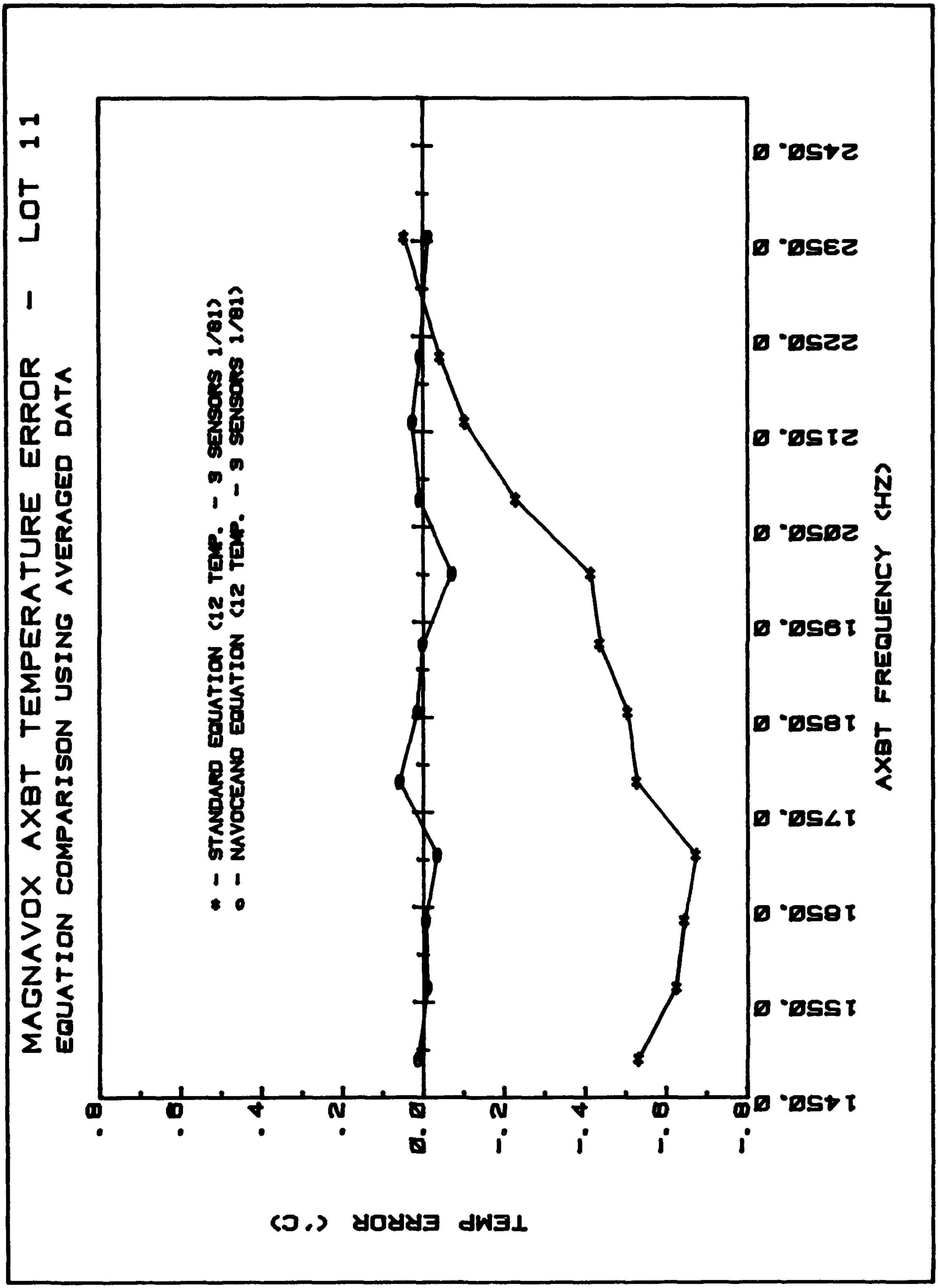
GRAPH 10


MAGNAVOX AXBT TEMPERATURE ERROR - LOT 5
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 4 SENSORS 1/81)
x - STANDARD EQUATION (4 TEMP. - 25 SENSORS 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 4 SENSORS 1/81)
⊡ - NAVOCEANO EQUATION (4 TEMP. - 25 SENSORS 1/81)
TEMP ERROR (°C)
.6
.4
.2
0.0
-.2
-.4
-.6
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

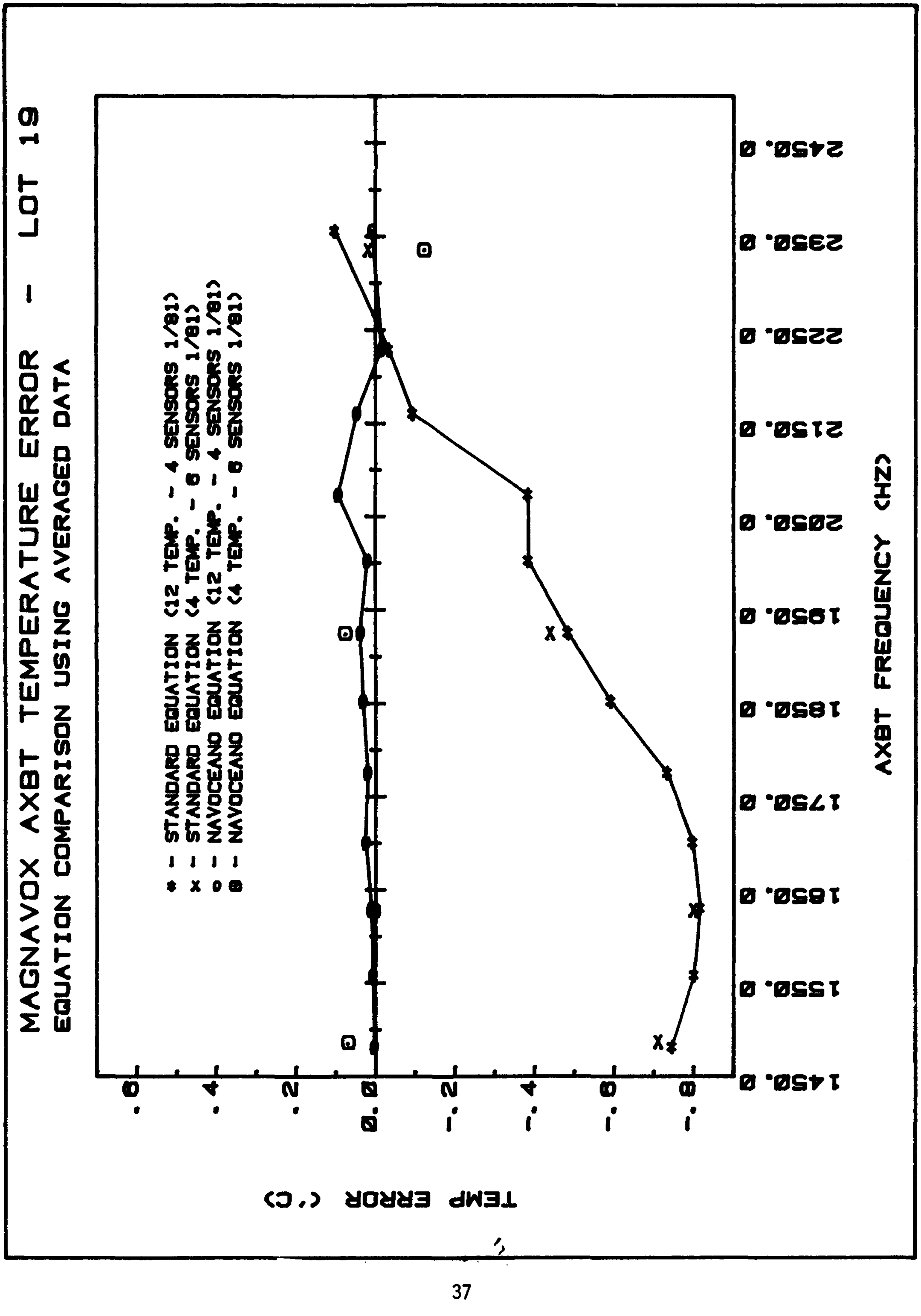
GRAPH 11


MAGNAVOX AXBT TEMPERATURE ERROR - LOT 7
EQUATION COMPARISON
* - STANDARD EQUATION (12 TEMP. - 1 SENSOR 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 1 SENSOR 1/81)
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

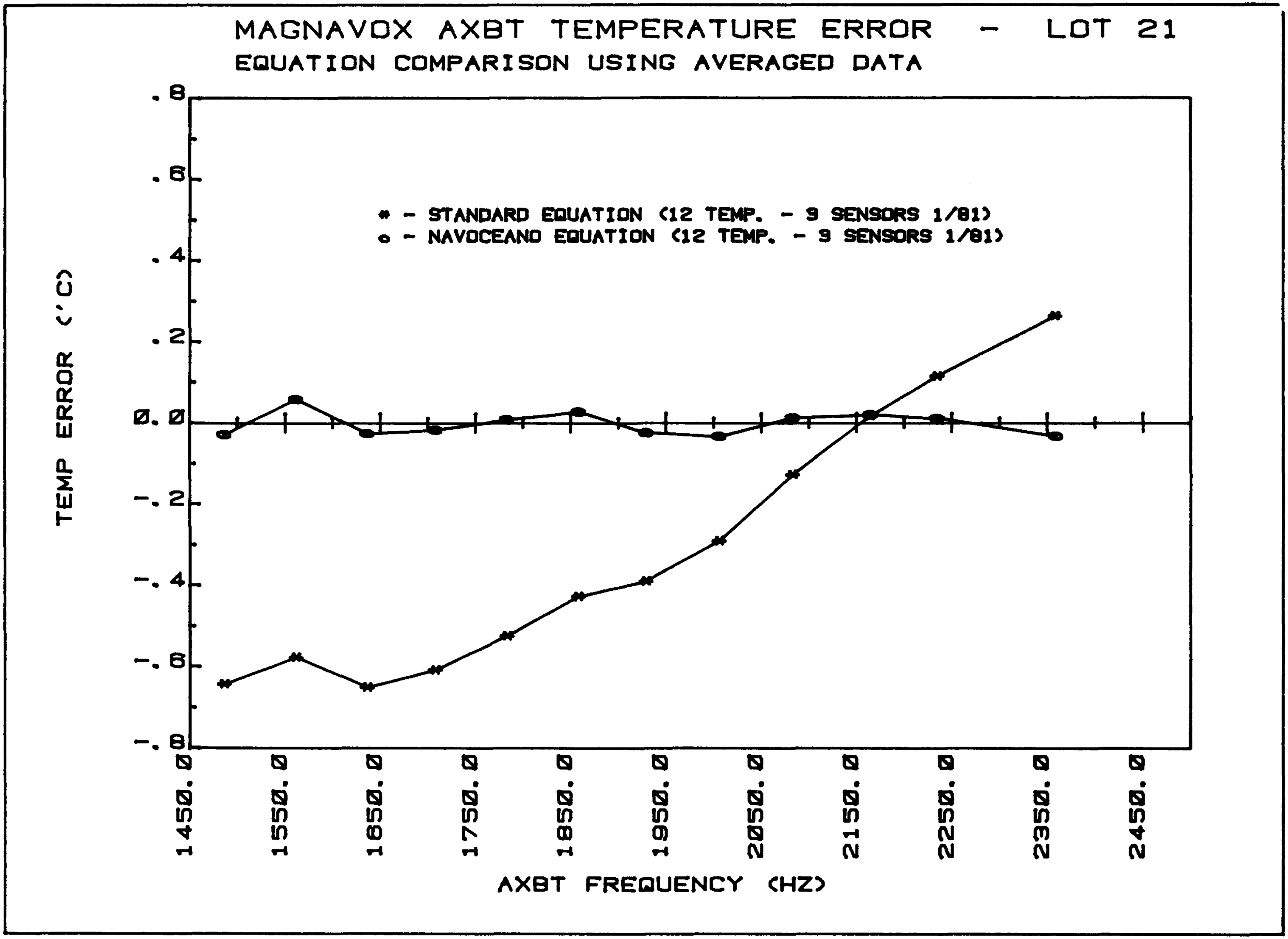
GRAPH 12


MAGNAVOX AXBT TEMPERATURE ERROR - LOT 11
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 9 SENSORS 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 9 SENSORS 1/81)
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

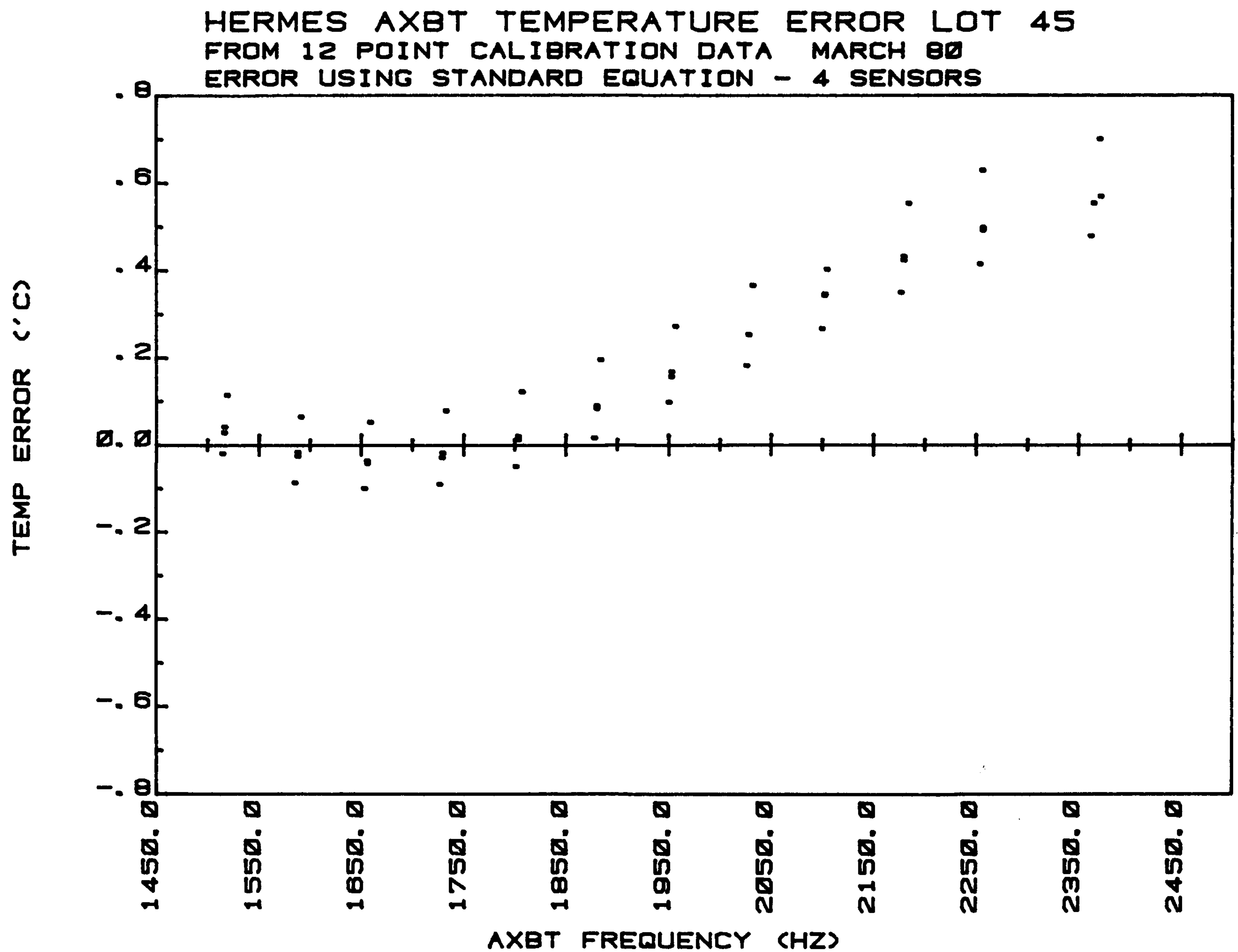
GRAPH 13


MAGNAVOX AXBT TEMPERATURE ERROR - LOT 19
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 4 SENSORS 1/81)
x - STANDARD EQUATION (4 TEMP. - 6 SENSORS 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 4 SENSORS 1/81)
⊕ - NAVOCEANO EQUATION (4 TEMP. - 6 SENSORS 1/81)
TEMP ERROR (°C)
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 14

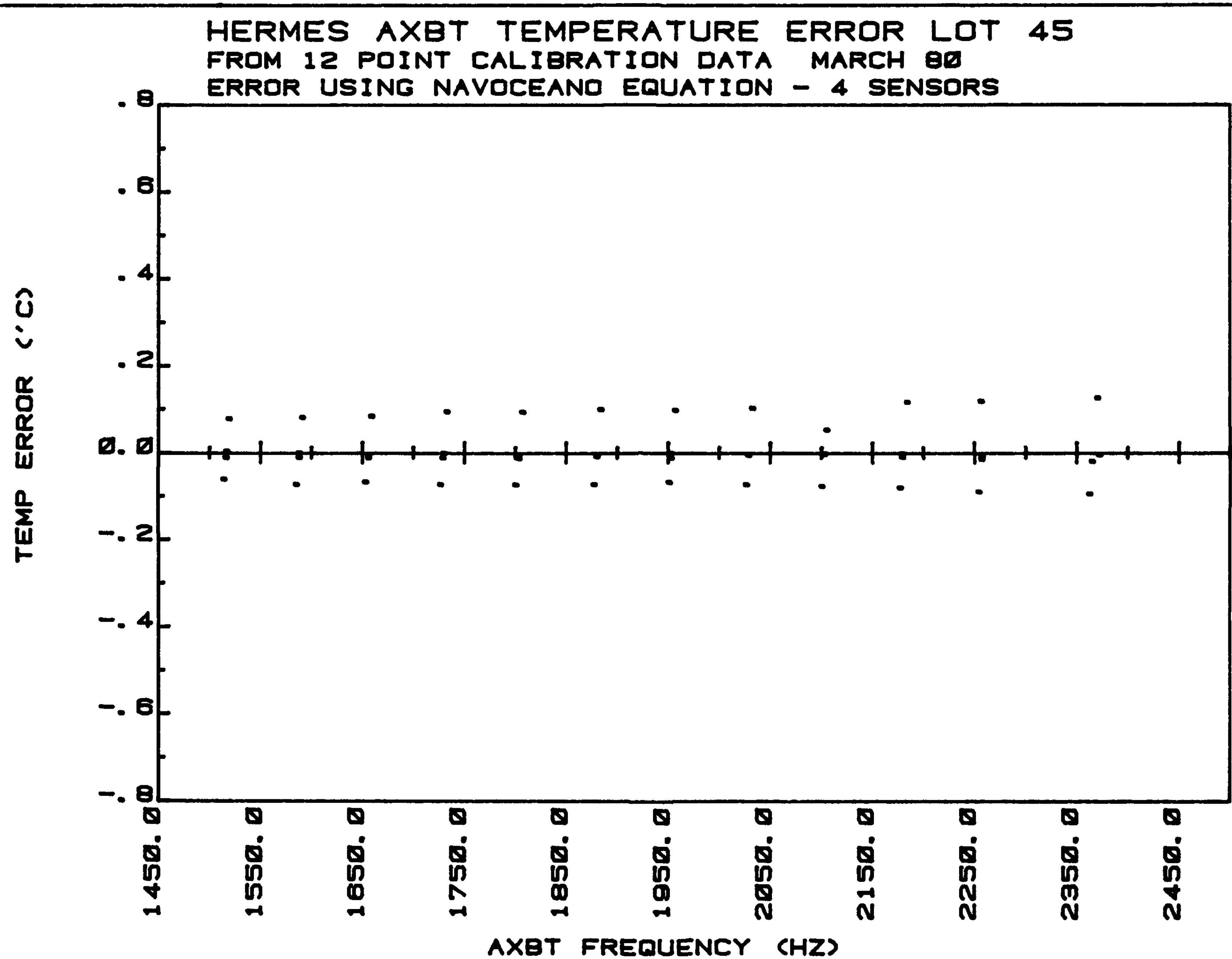

MAGNAVOX AXBT TEMPERATURE ERROR - LOT 21
EQUATION COMPARISON USING AVERAGED DATA
* - STANDARD EQUATION (12 TEMP. - 9 SENSORS 1/81)
o - NAVOCEANO EQUATION (12 TEMP. - 9 SENSORS 1/81)
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 15

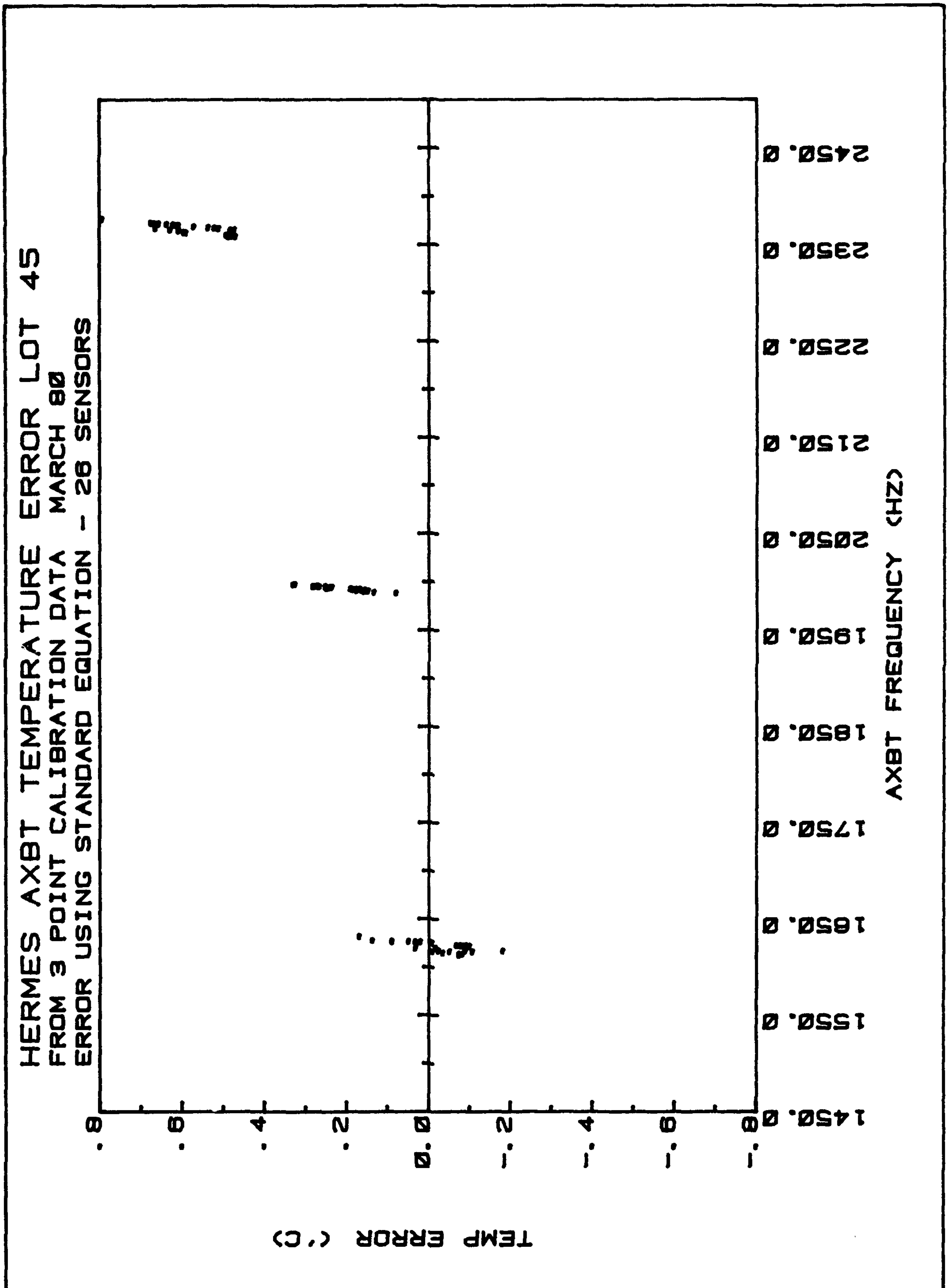


HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 12 POINT CALIBRATION DATA MARCH 80
ERROR USING STANDARD EQUATION - 4 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

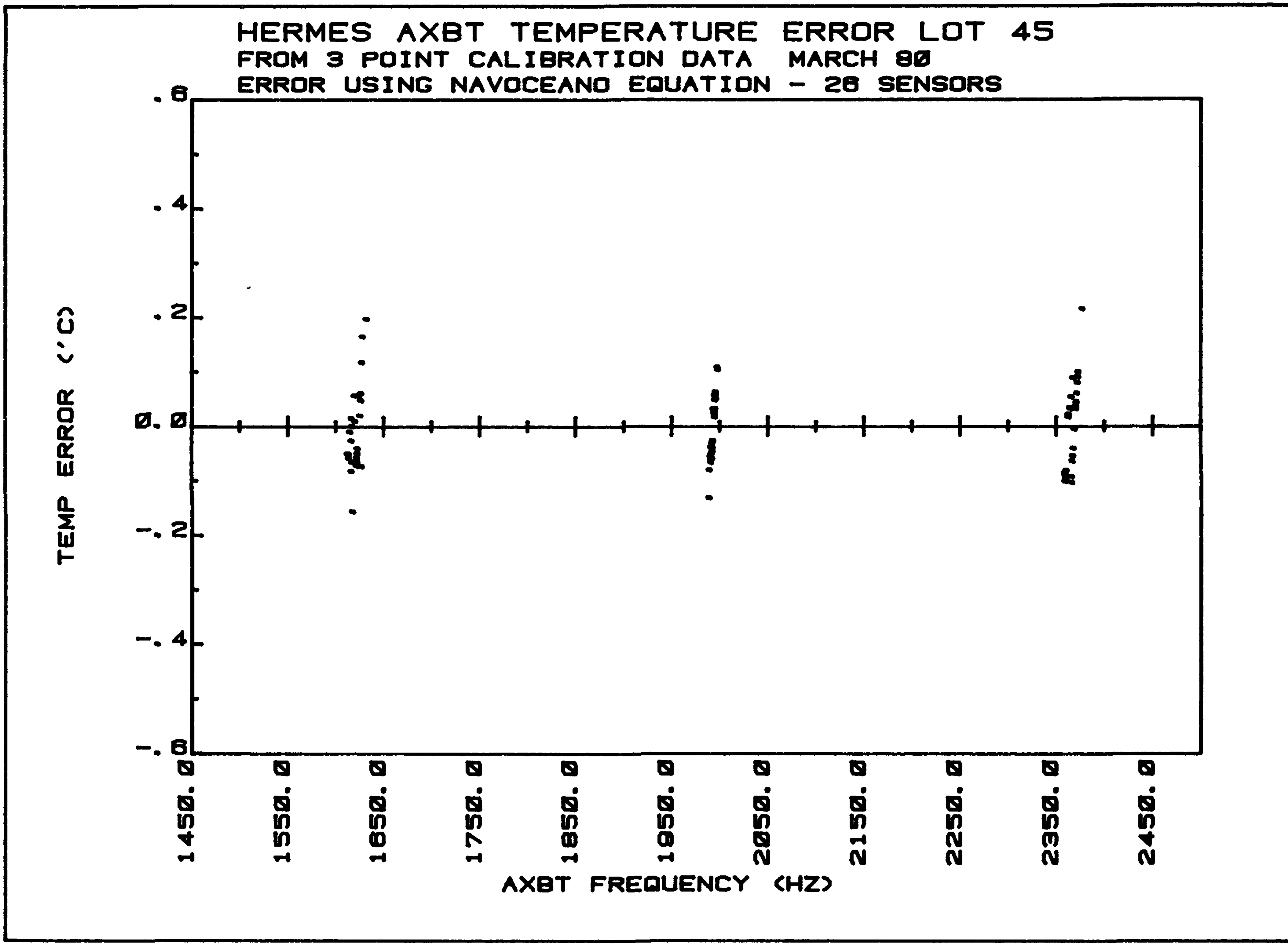
GRAPH 16


HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 12 POINT CALIBRATION DATA MARCH 80
ERROR USING NAVOCEANO EQUATION - 4 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 17

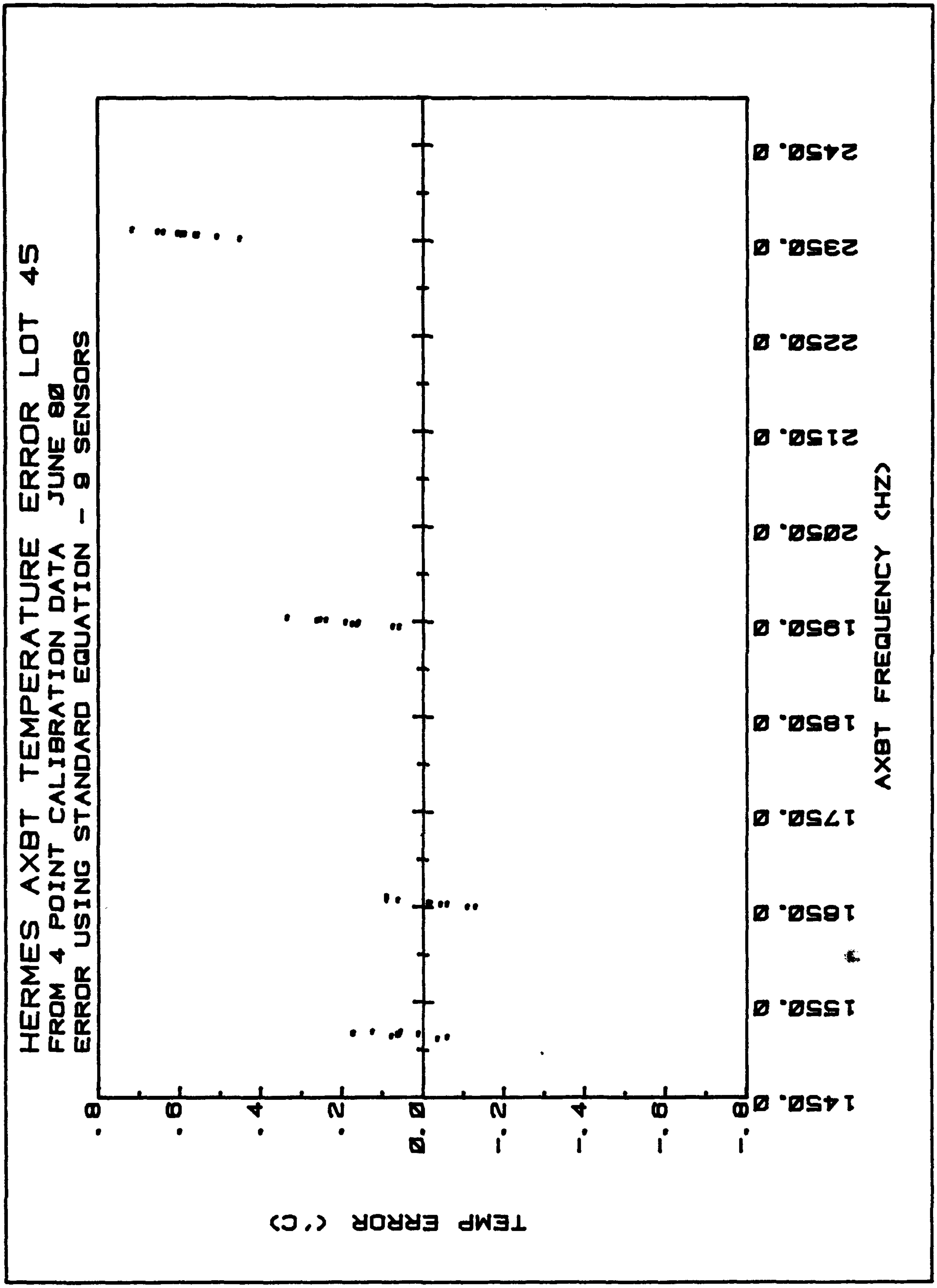

HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 3 POINT CALIBRATION DATA MARCH 80
ERROR USING STANDARD EQUATION - 26 SENSORS
TEMP ERROR (C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 18

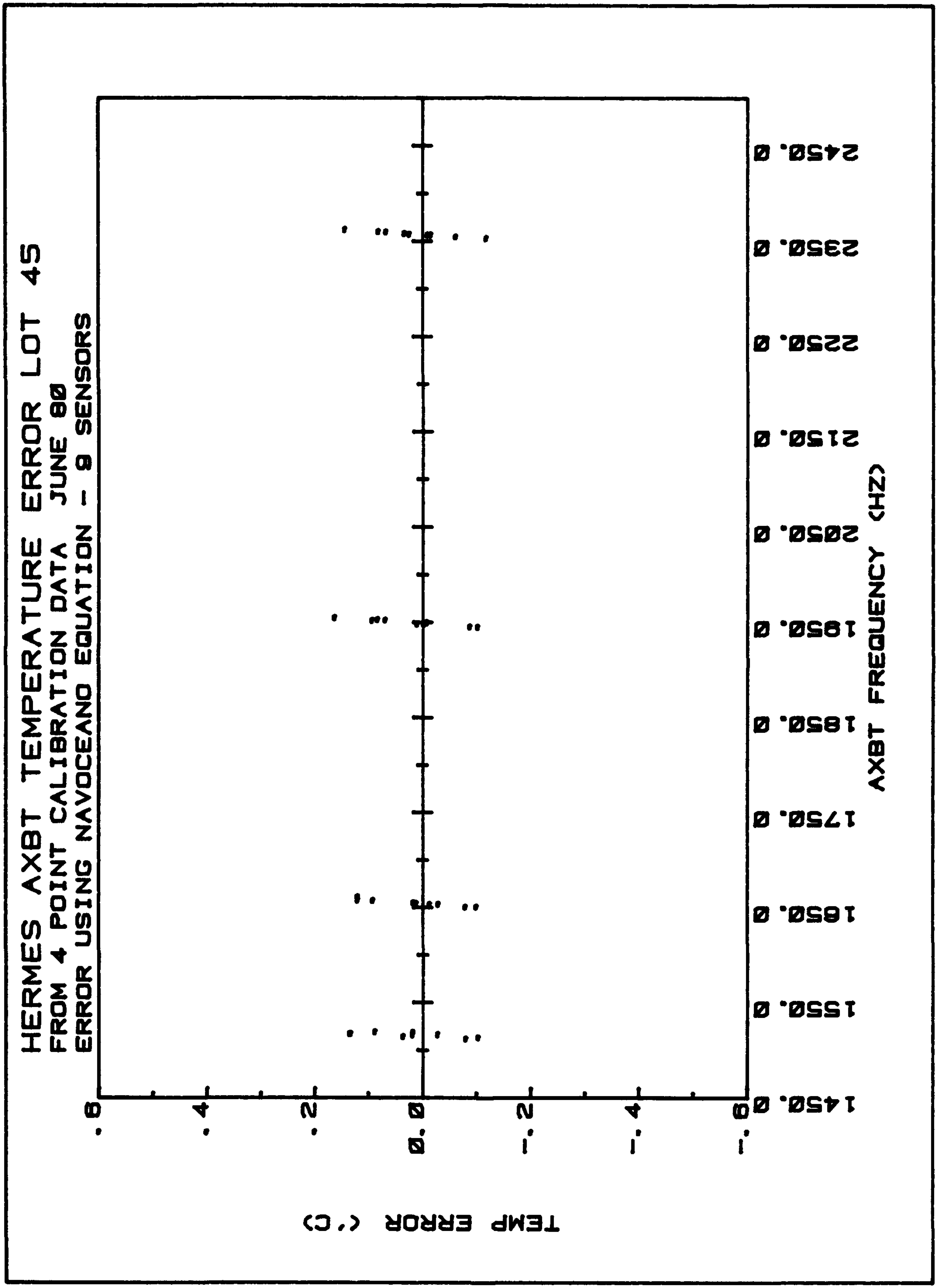


HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 3 POINT CALIBRATION DATA MARCH 80
ERROR USING NAVOCEANO EQUATION - 26 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

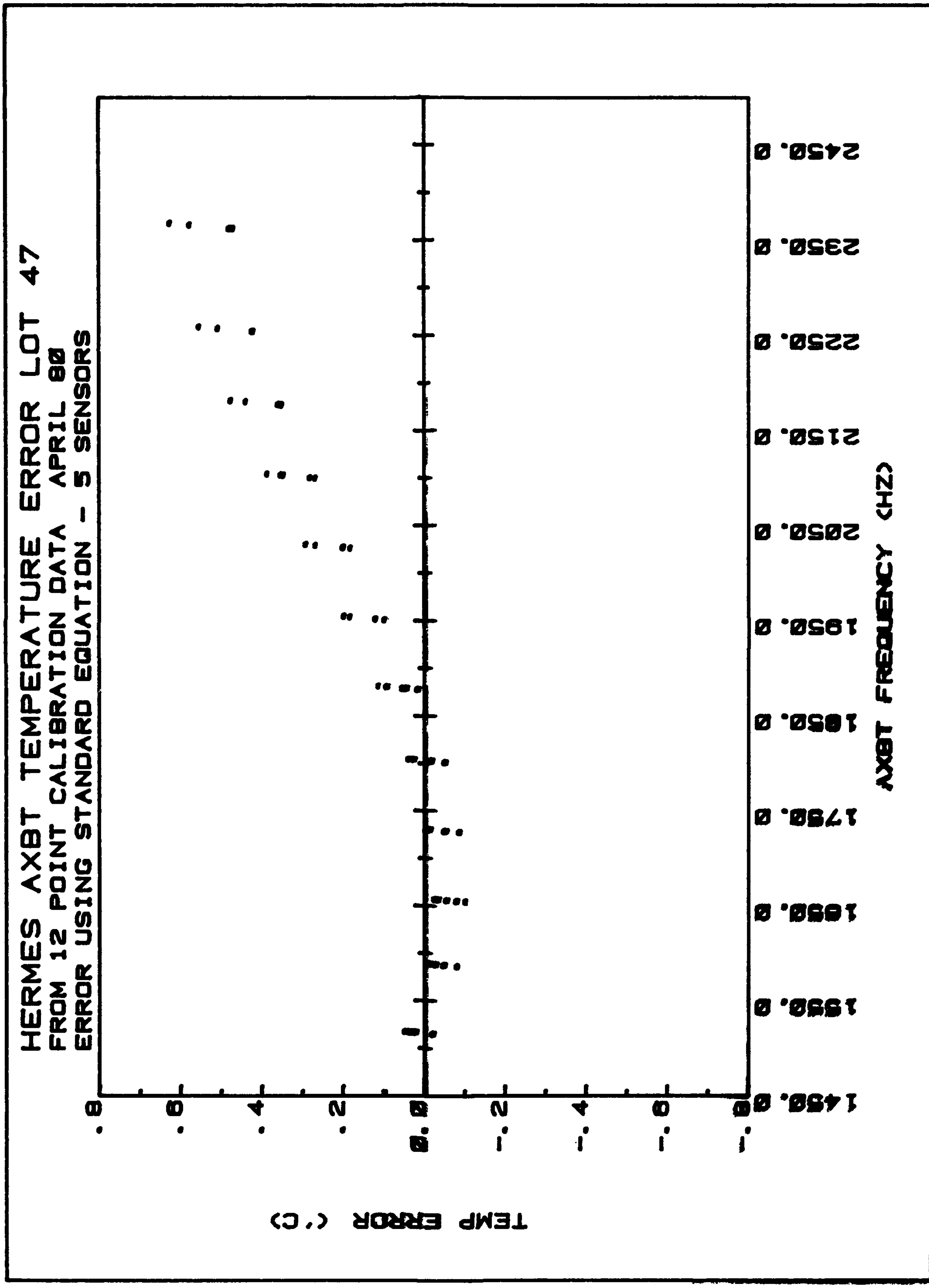
GRAPH 19


HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 4 POINT CALIBRATION DATA JUNE 80
ERROR USING STANDARD EQUATION - 9 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

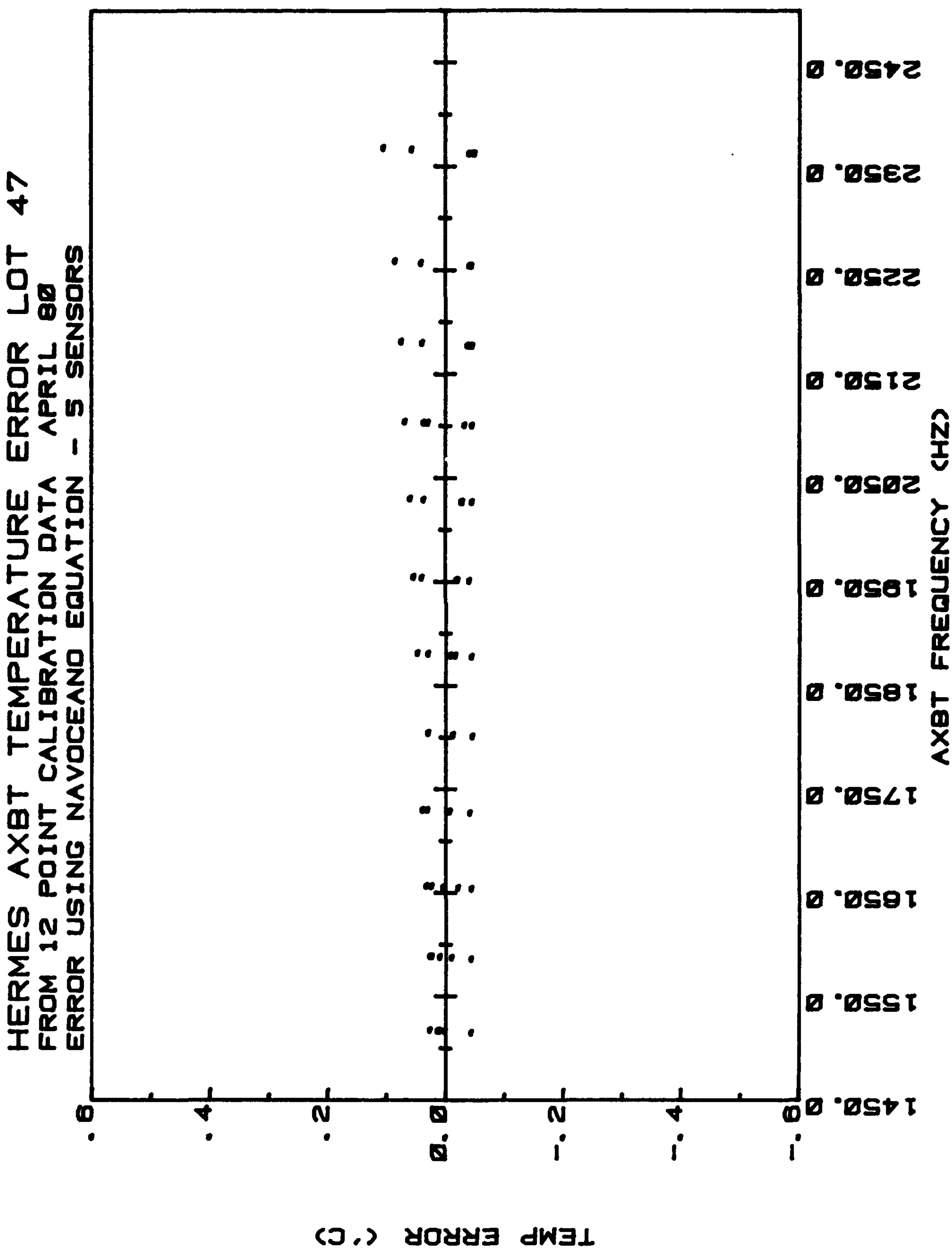
GRAPH 20


HERMES AXBT TEMPERATURE ERROR LOT 45
FROM 4 POINT CALIBRATION DATA JUNE 80
ERROR USING NAVOCEANO EQUATION - 9 SENSORS
TEMP ERROR (°C)
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
0.0

GRAPH 21

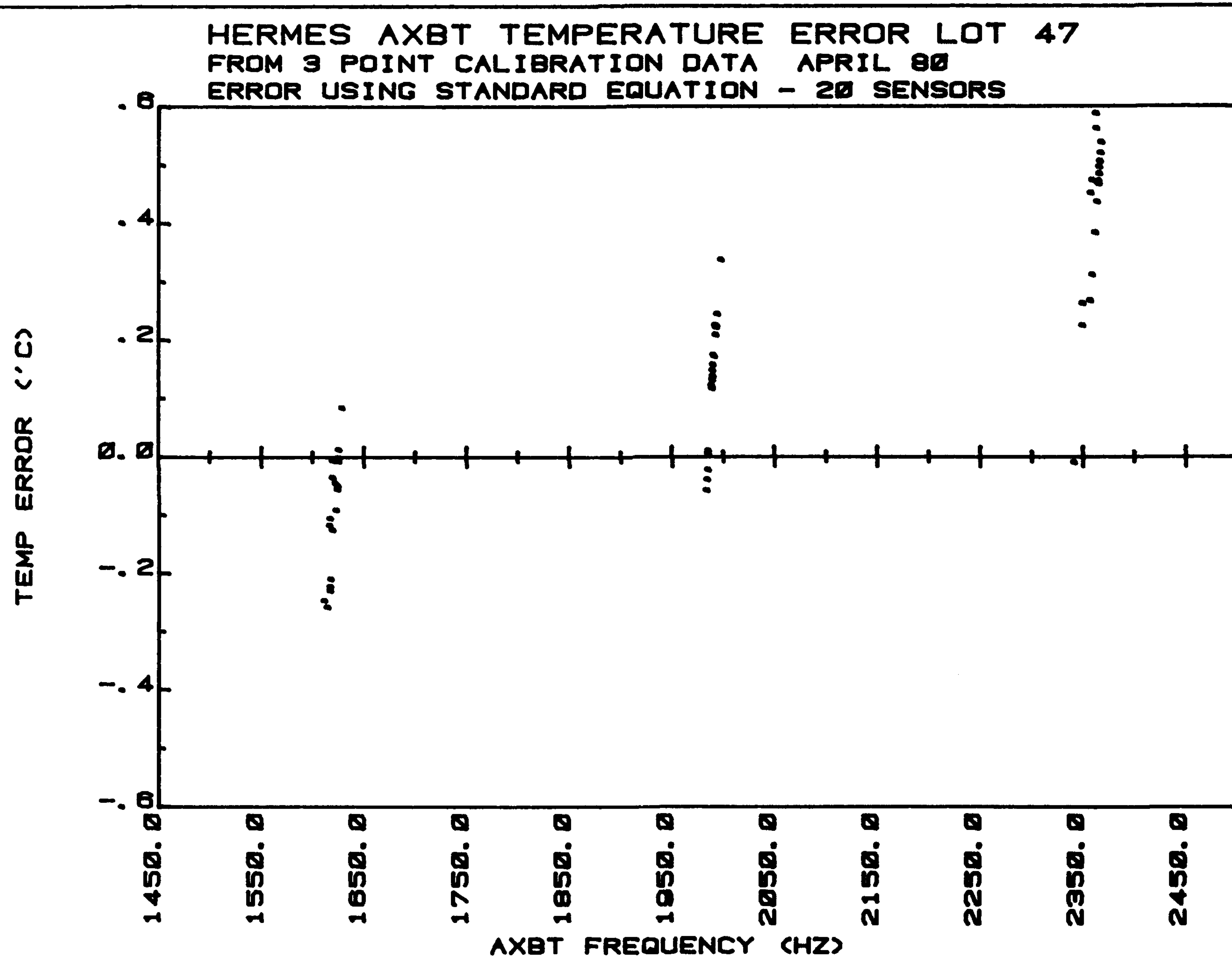

HERMES AXBT TEMPERATURE ERROR LOT 47
FROM 12 POINT CALIBRATION DATA APRIL 80
ERROR USING STANDARD EQUATION - 5 SENSORS
TEMP ERROR (°C)
.8
.6
.4
.2
0.
-.2
-.4
-.6
-.8
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 22



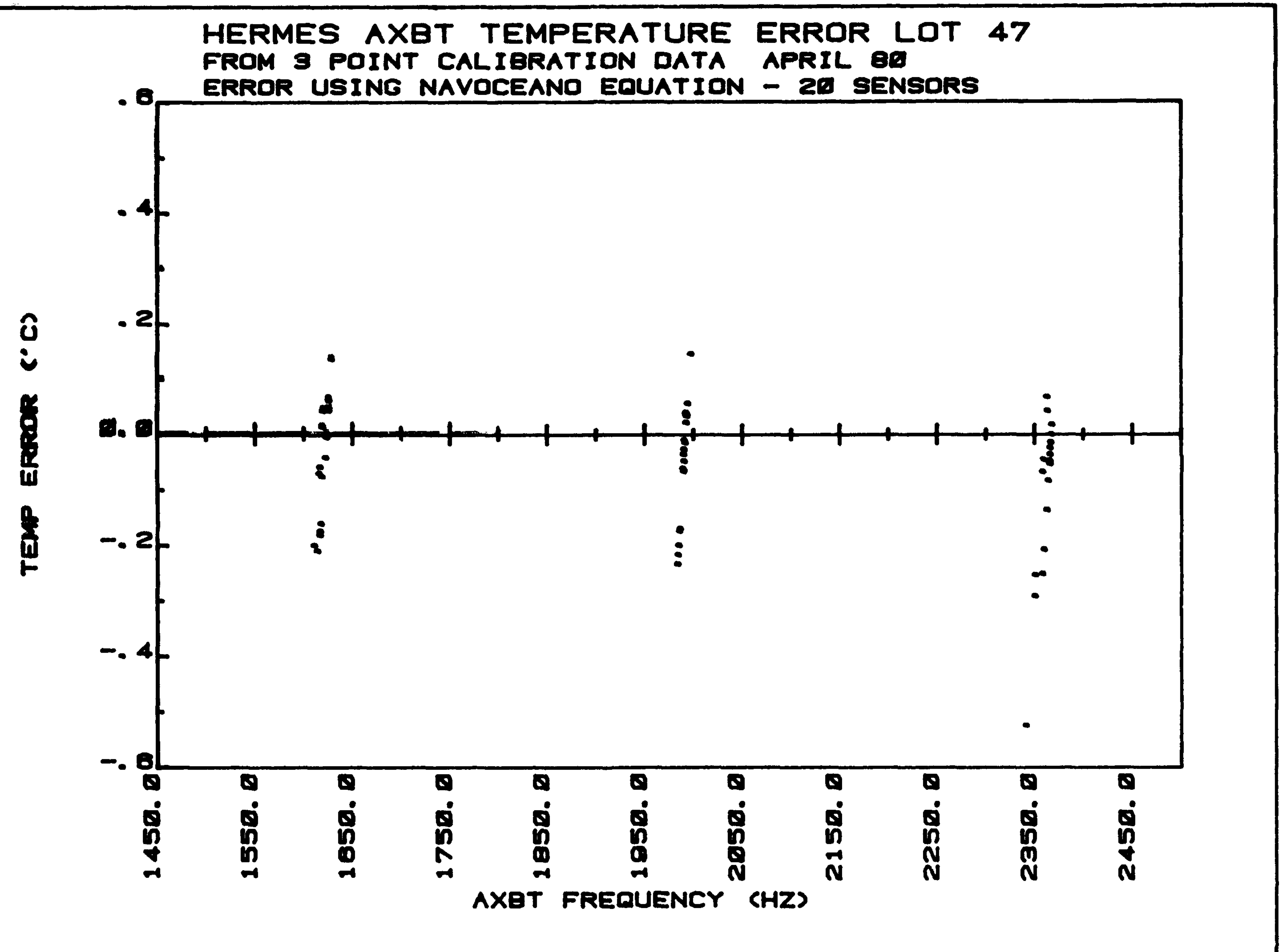
HERMES AXBT TEMPERATURE ERROR LOT 47
FROM 12 POINT CALIBRATION DATA APRIL 80
ERROR USING NAVOCEANO EQUATION - 5 SENSORS
AXBT FREQUENCY (HZ)
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
.6
.4
.2
0.0
-.2
-.4
-.6

GRAPH 23

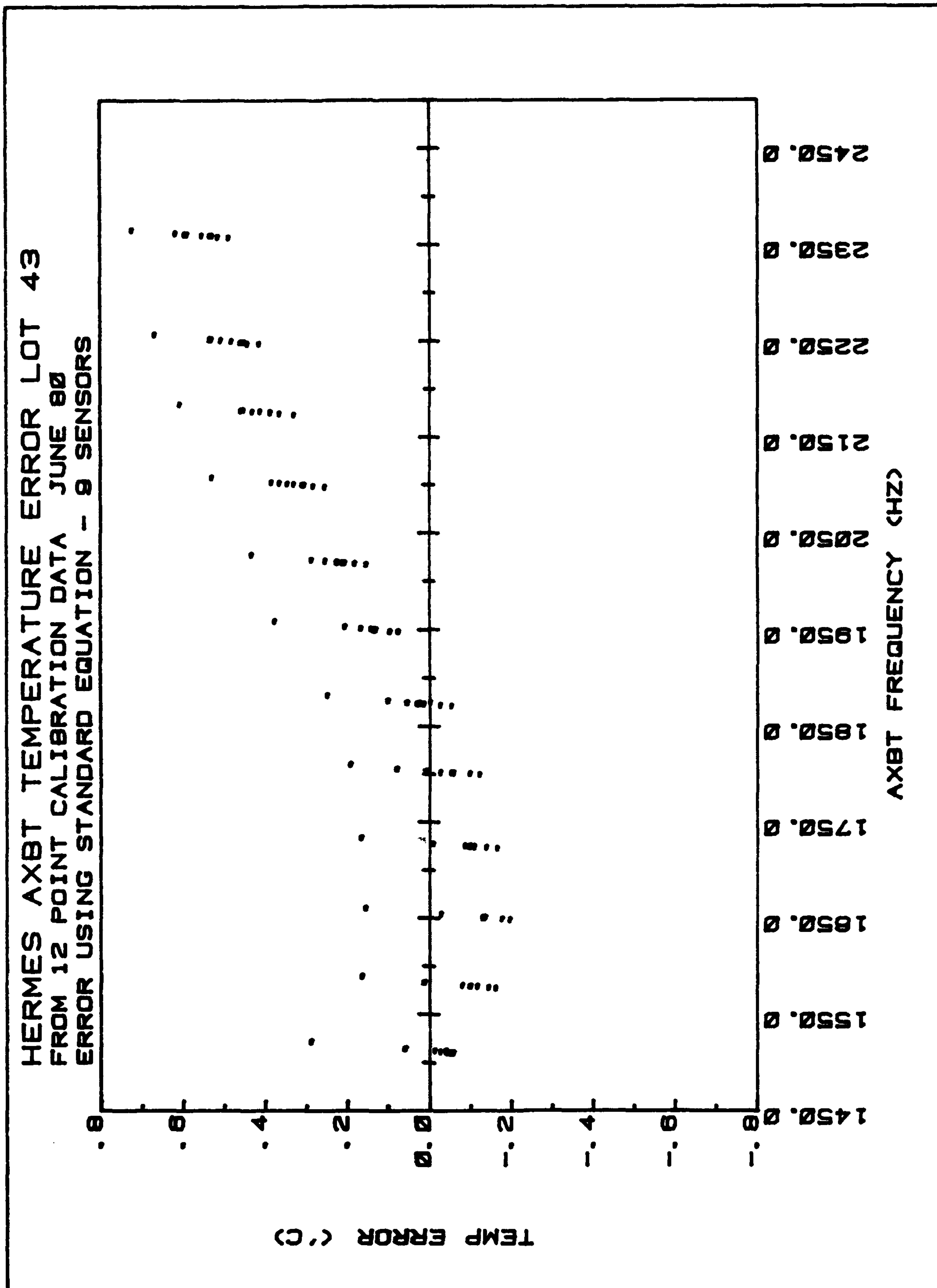


HERMES AXBT TEMPERATURE ERROR LOT 47
FROM 3 POINT CALIBRATION DATA APRIL 80
ERROR USING STANDARD EQUATION - 20 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

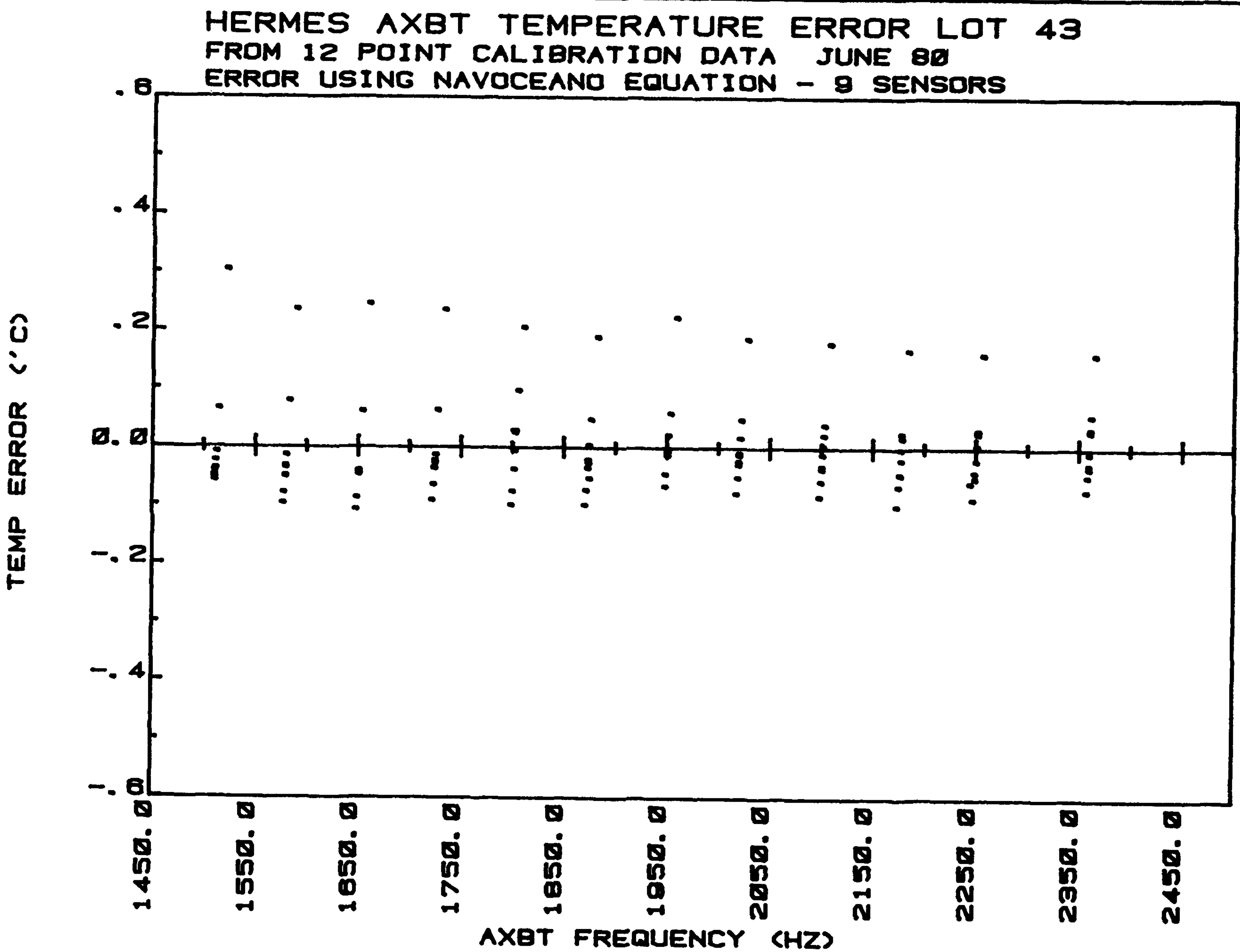
GRAPH 24


HERMES AXBT TEMPERATURE ERROR LOT 47
FROM 3 POINT CALIBRATION DATA APRIL 80
ERROR USING NAVOCEANO EQUATION - 20 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

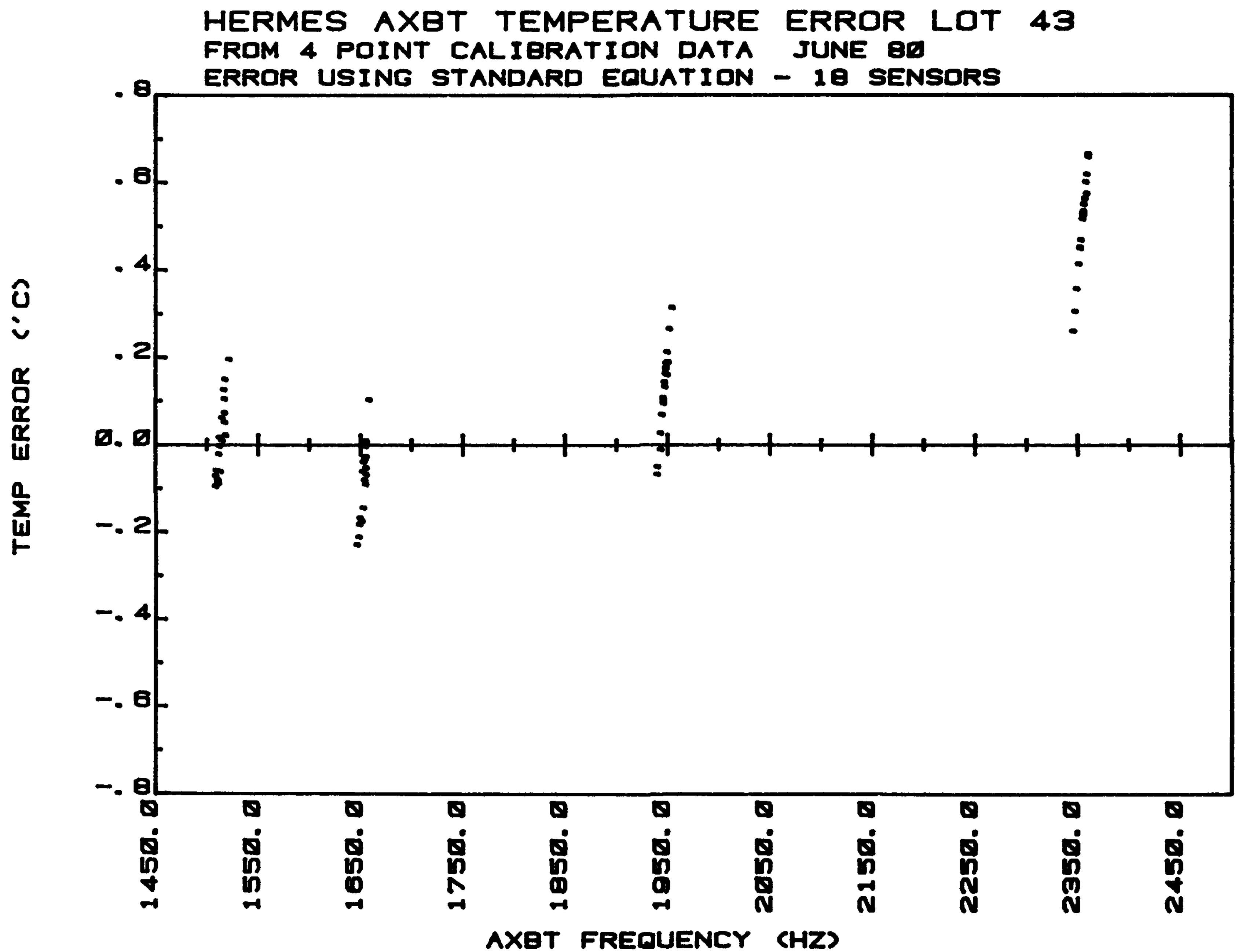
GRAPH 25


HERMES AXBT TEMPERATURE ERROR LOT 43
FROM 12 POINT CALIBRATION DATA JUNE 80
ERROR USING STANDARD EQUATION - 9 SENSORS
TEMP ERROR (°C)
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 26

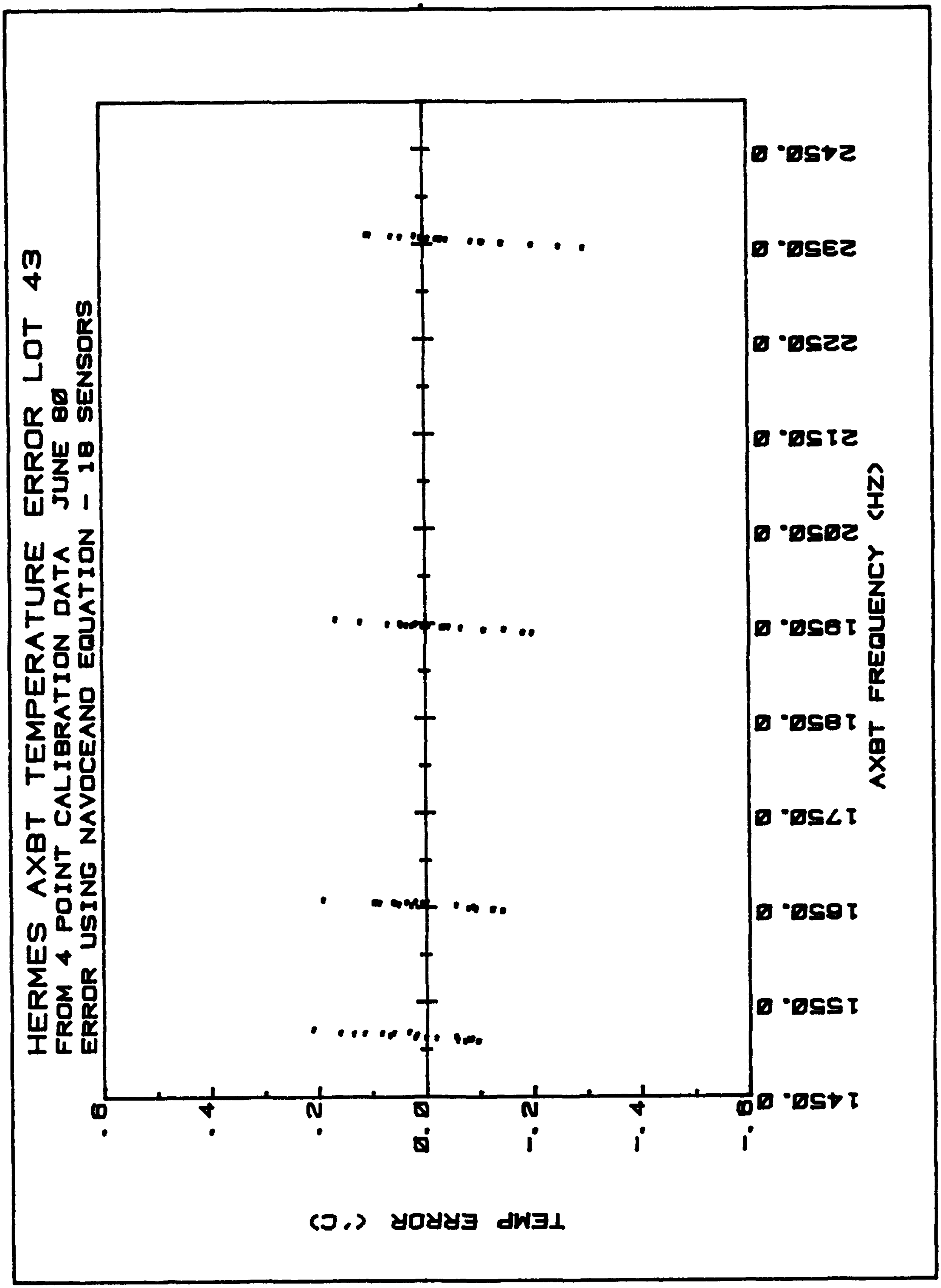

HERMES AXBT TEMPERATURE ERROR LOT 43
FROM 12 POINT CALIBRATION DATA JUNE 80
ERROR USING NAVOCEANO EQUATION - 9 SENSORS
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 27

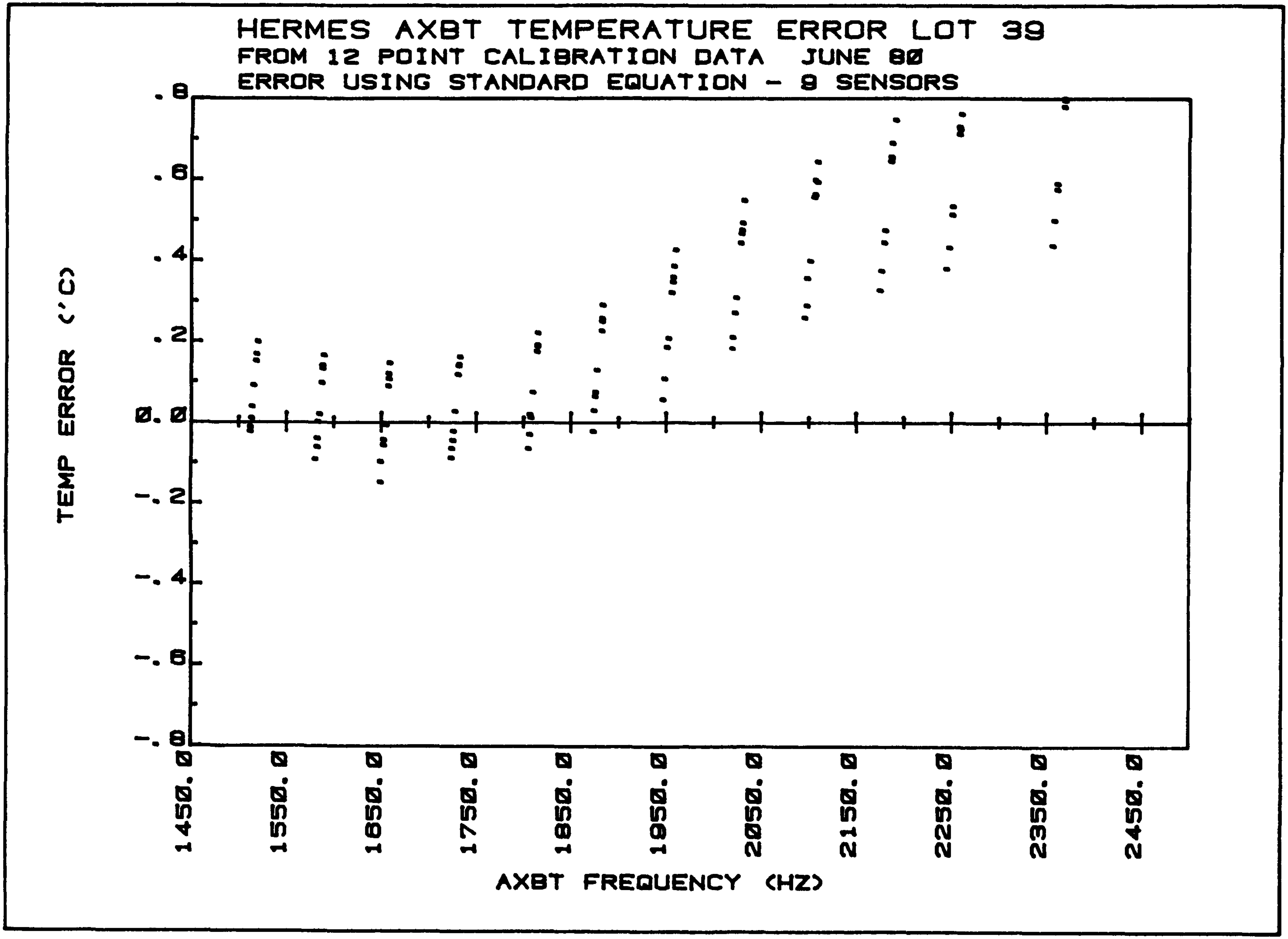


HERMES AXBT TEMPERATURE ERROR LOT 43
FROM 4 POINT CALIBRATION DATA JUNE 80
ERROR USING STANDARD EQUATION - 18 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

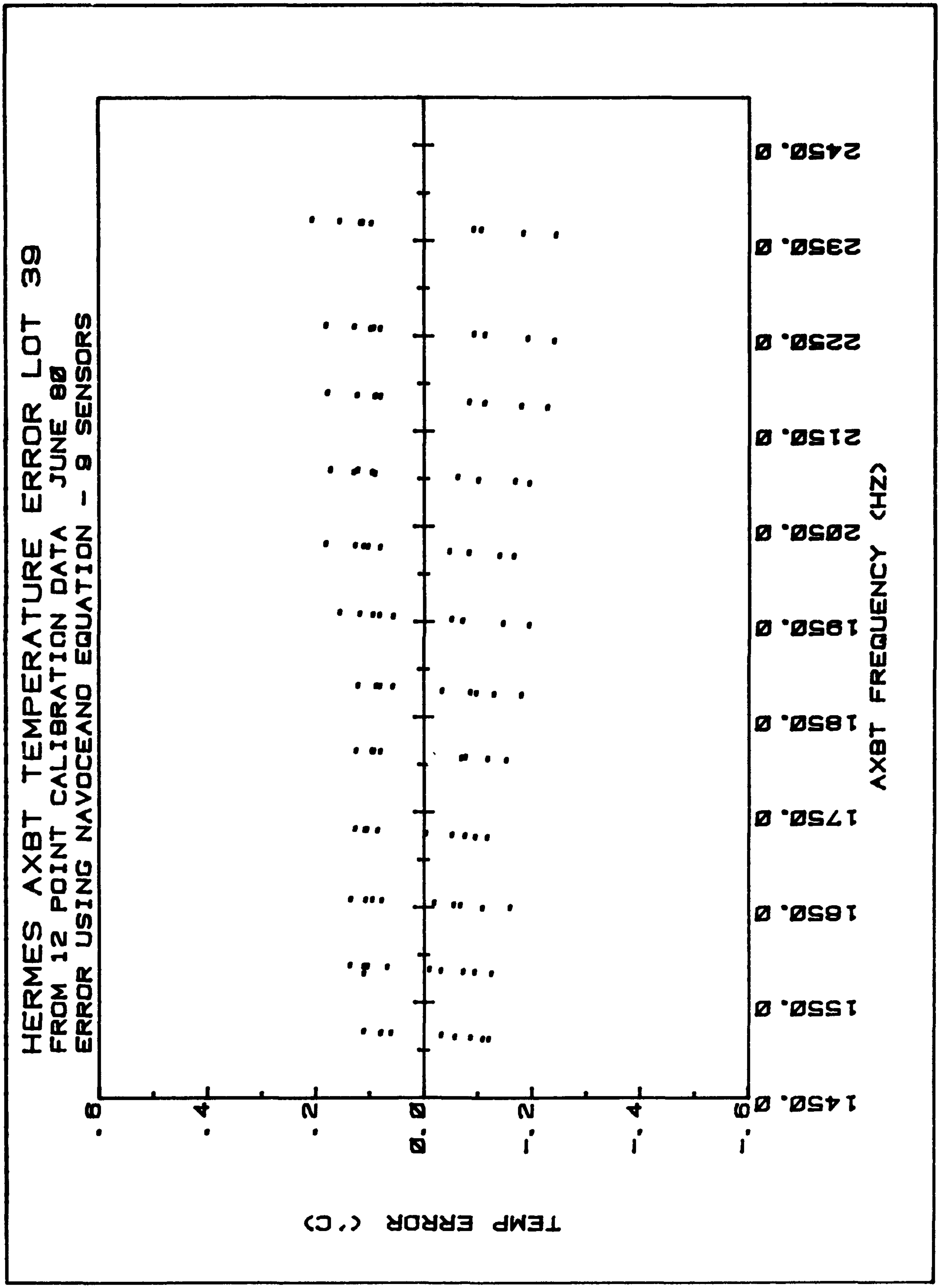
GRAPH 28


HERMES AXBT TEMPERATURE ERROR LOT 43
FROM 4 POINT CALIBRATION DATA JUNE 80
ERROR USING NAVOCEANO EQUATION - 18 SENSORS
TEMP ERROR (°C)
.8
.4
.2
0.0
-.2
-.4
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

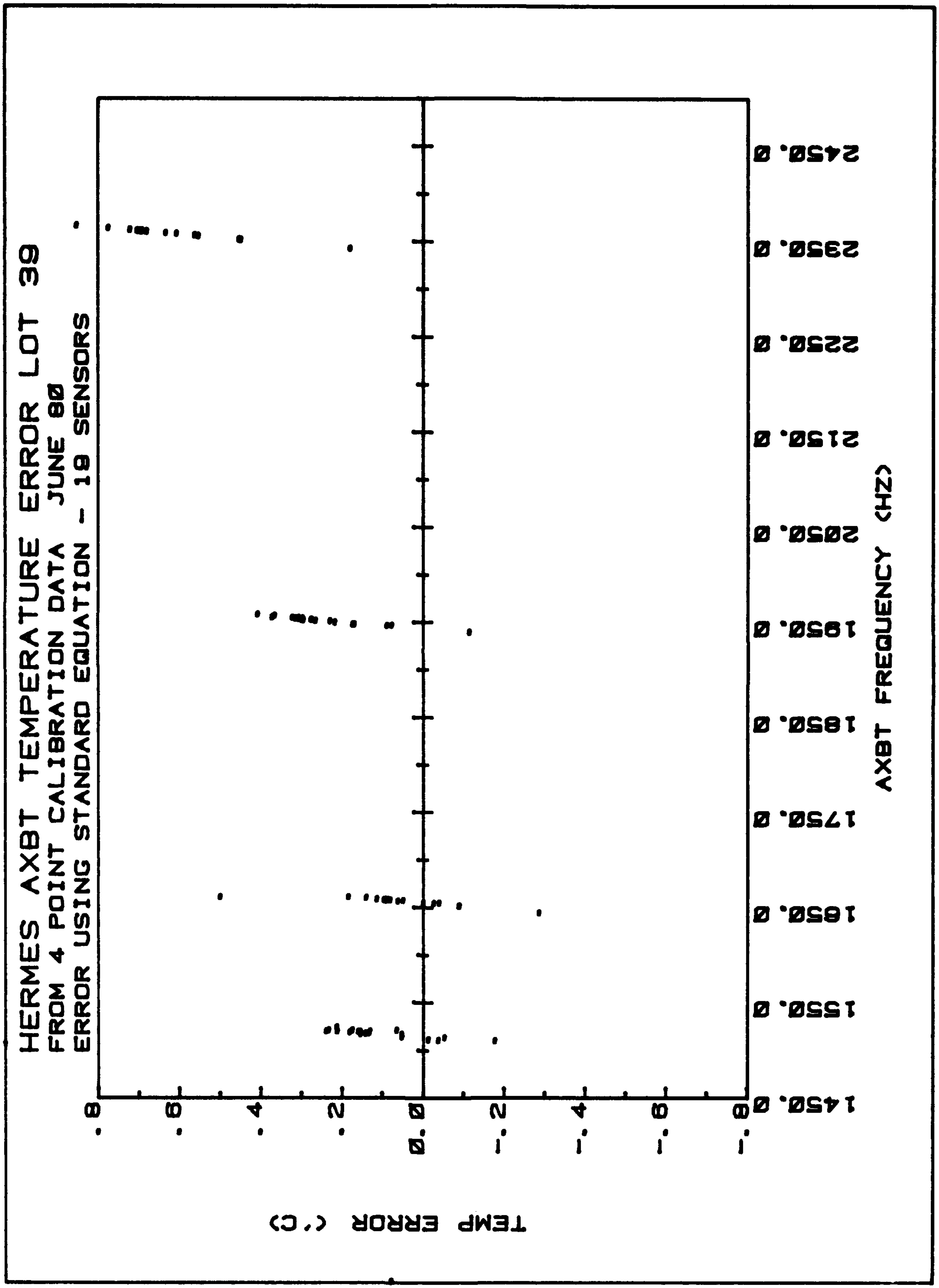
GRAPH 29


HERMES AXBT TEMPERATURE ERROR LOT 39
FROM 12 POINT CALIBRATION DATA JUNE 80
ERROR USING STANDARD EQUATION - 9 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

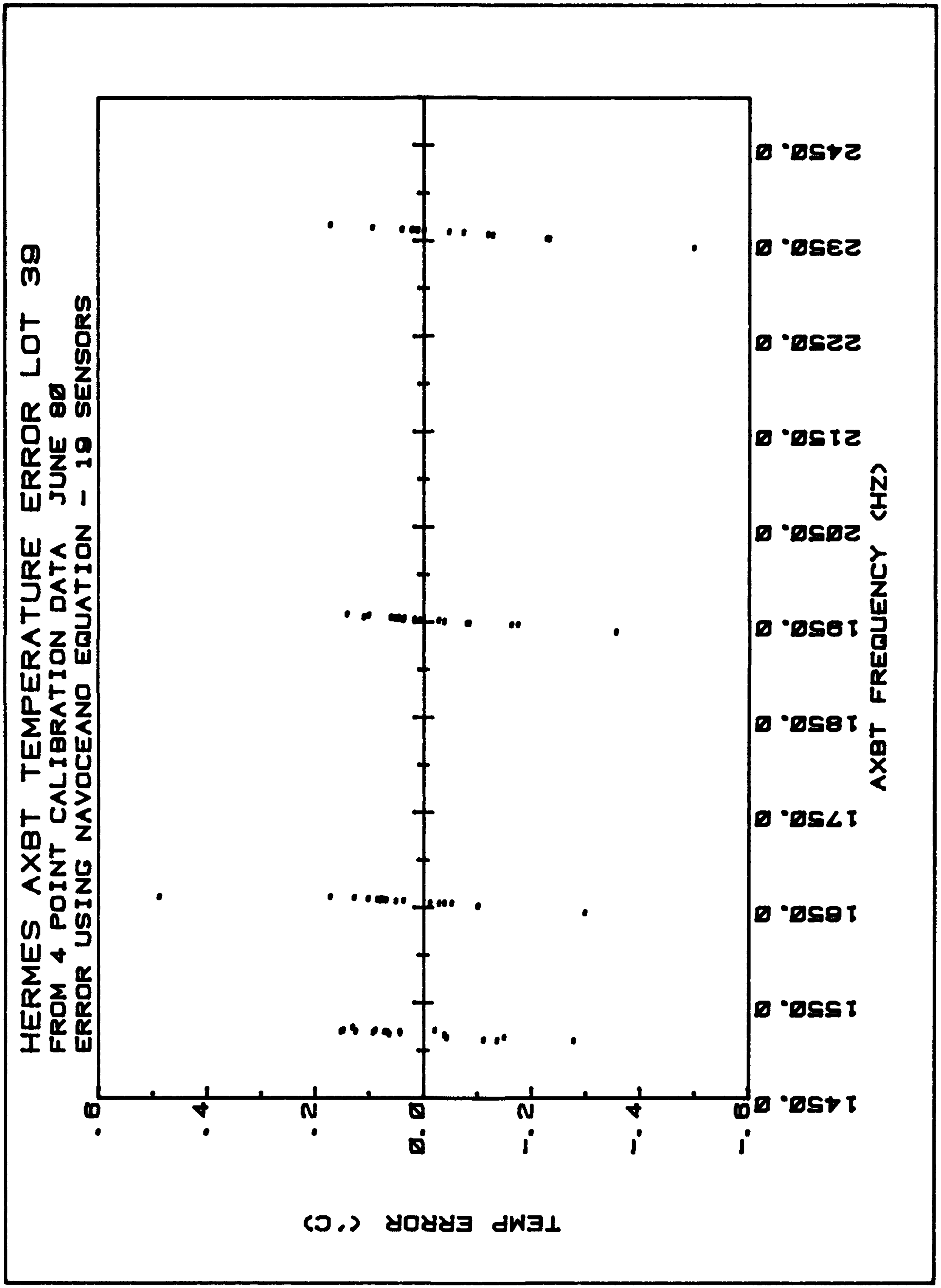
GRAPH 30


HERMES AXBT TEMPERATURE ERROR LOT 39
FROM 12 POINT CALIBRATION DATA JUNE 80
ERROR USING NAVOCEANO EQUATION - 9 SENSORS
TEMP ERROR ('C)
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
.8
.4
.0
-.2
-.4
-.6

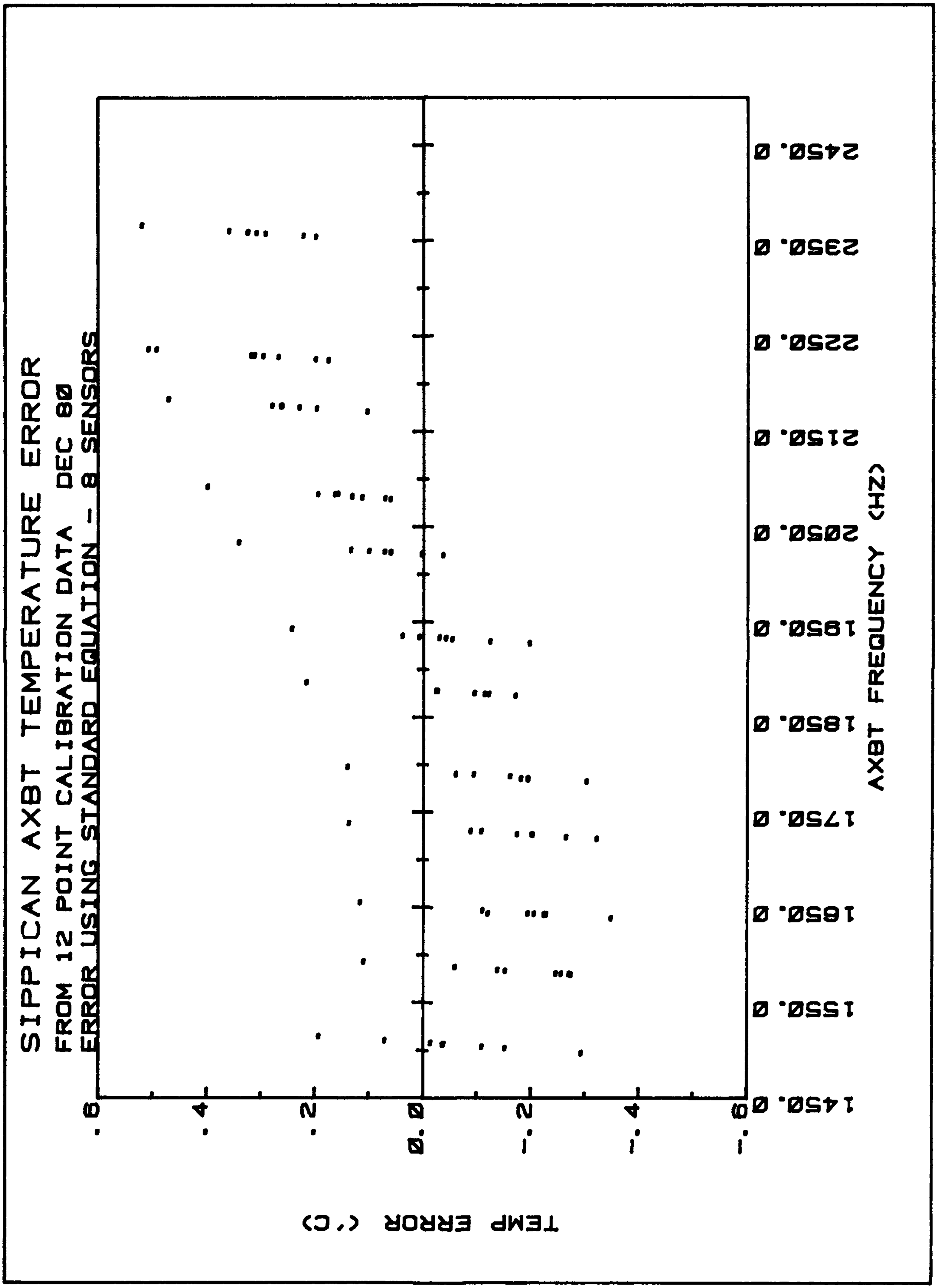
GRAPH 31


HERMES AXBT TEMPERATURE ERROR LOT 39
FROM 4 POINT CALIBRATION DATA JUNE 8Ø
ERROR USING STANDARD EQUATION - 1Ø SENSORS
.8
.6
.4
.2
Ø.Ø
-.2
-.4
-.6
-.8
TEMP ERROR ('C)
1450.Ø
1550.Ø
1650.Ø
1750.Ø
1850.Ø
1950.Ø
2050.Ø
2150.Ø
2250.Ø
2350.Ø
2450.Ø
AXBT FREQUENCY (HZ)

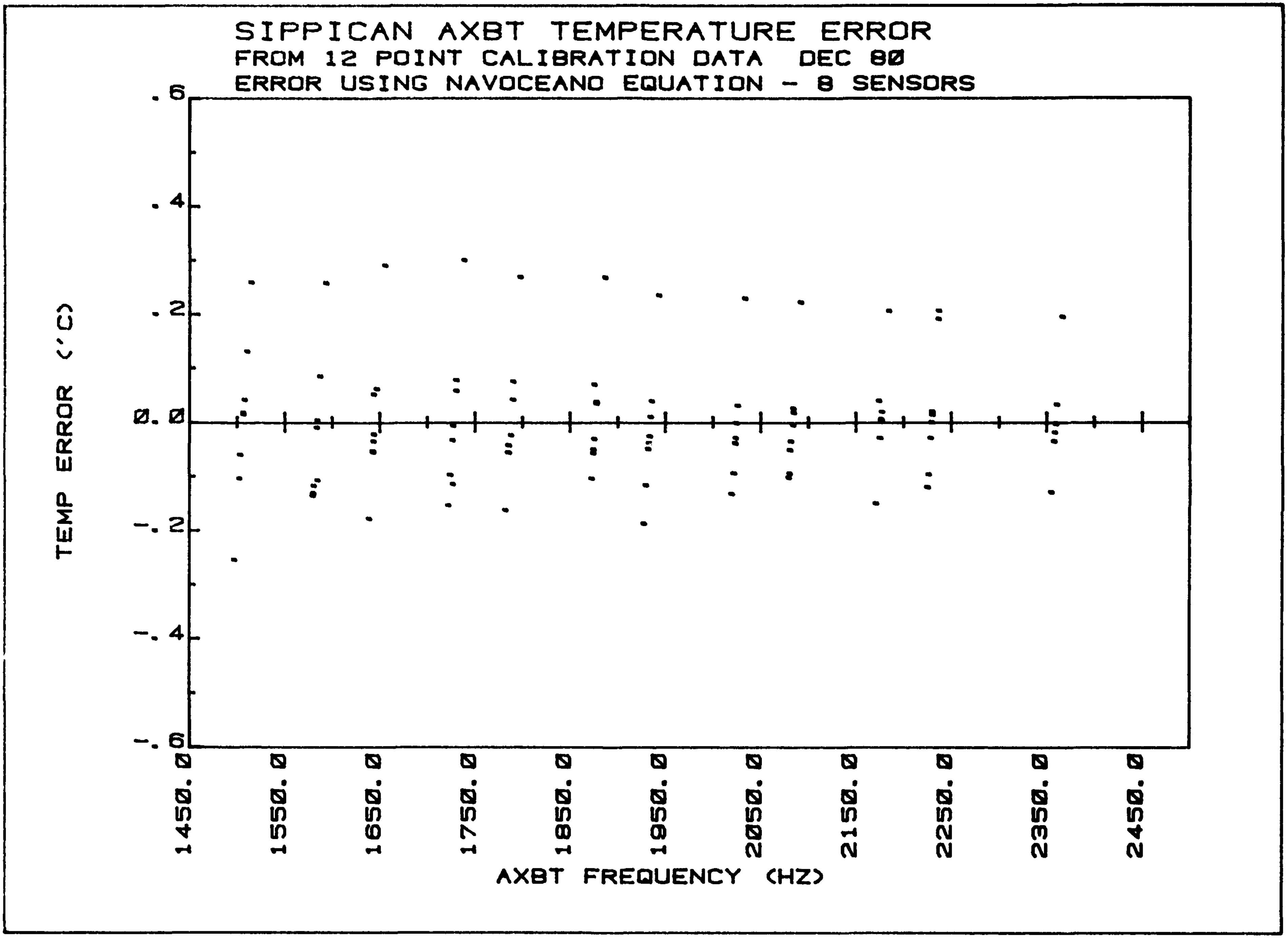
GRAPH 32


HERMES AXBT TEMPERATURE ERROR LOT 39
FROM 4 POINT CALIBRATION DATA JUNE 80
ERROR USING NAVOCEANO EQUATION - 19 SENSORS
AXBT FREQUENCY (HZ)
TEMP ERROR (°C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
.6
.4
.2
0.0
-.2
-.4
-.6

GRAPH 33

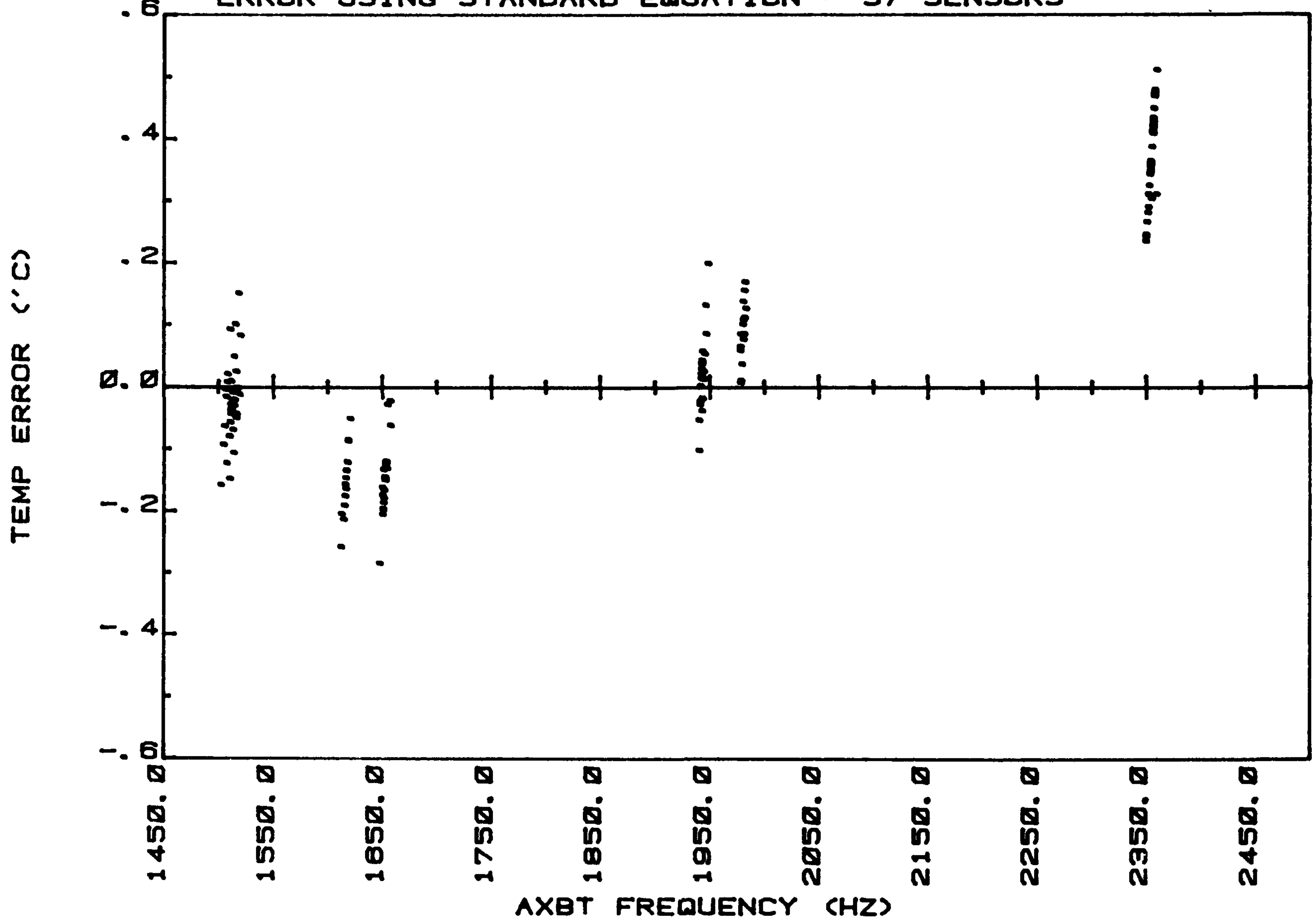

SIPPICAN AXBT TEMPERATURE ERROR
FROM 12 POINT CALIBRATION DATA DEC 80
ERROR USING STANDARD EQUATION - 8 SENSORS
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 34

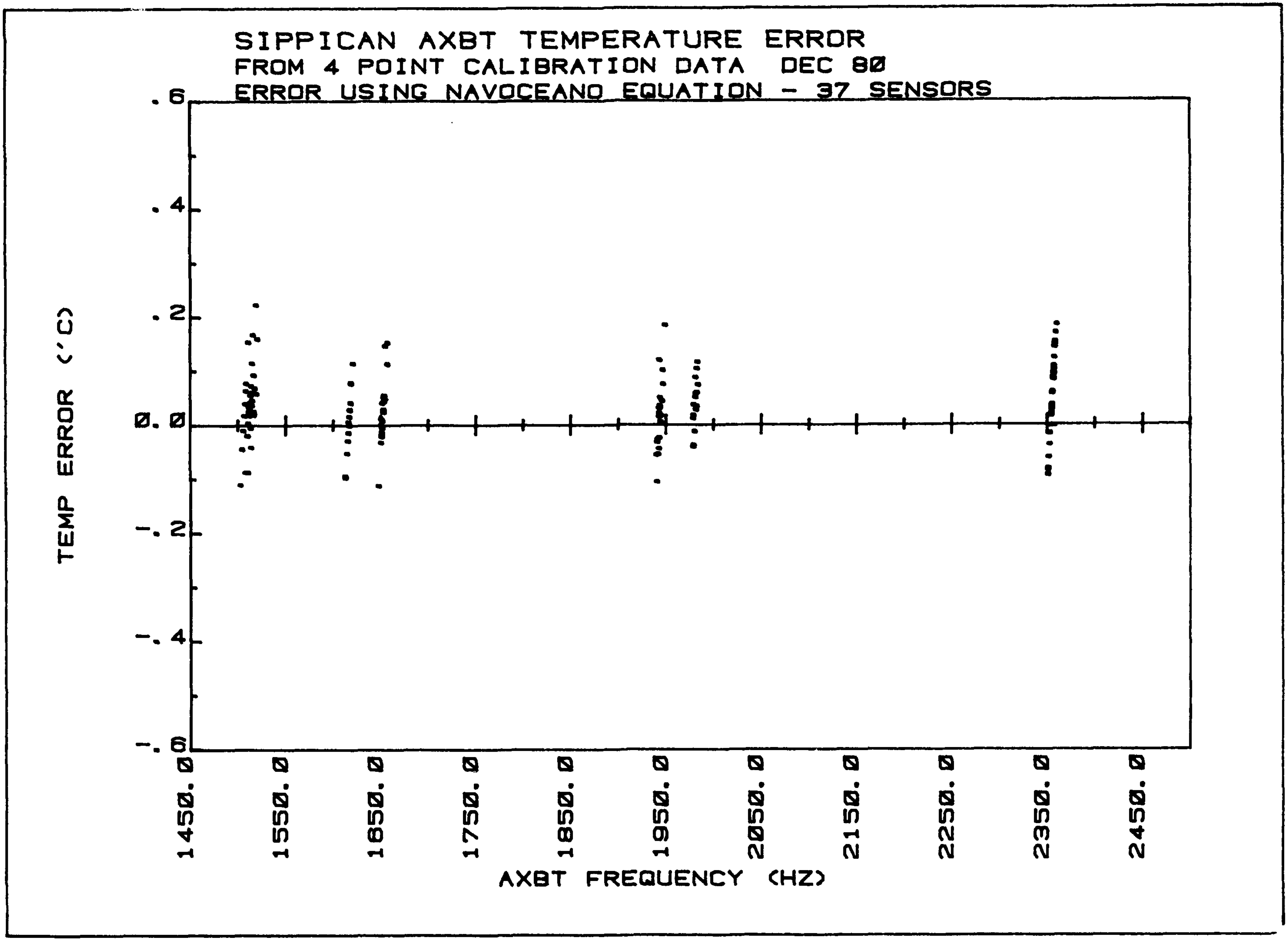

SIPPICAN AXBT TEMPERATURE ERROR
FROM 12 POINT CALIBRATION DATA DEC 80
ERROR USING NAVOCEANO EQUATION - 8 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 35

SIPPICAN AXBT TEMPERATURE ERROR
FROM 4 POINT CALIBRATION DATA DEC 80
ERROR USING STANDARD EQUATION - 37 SENSORS

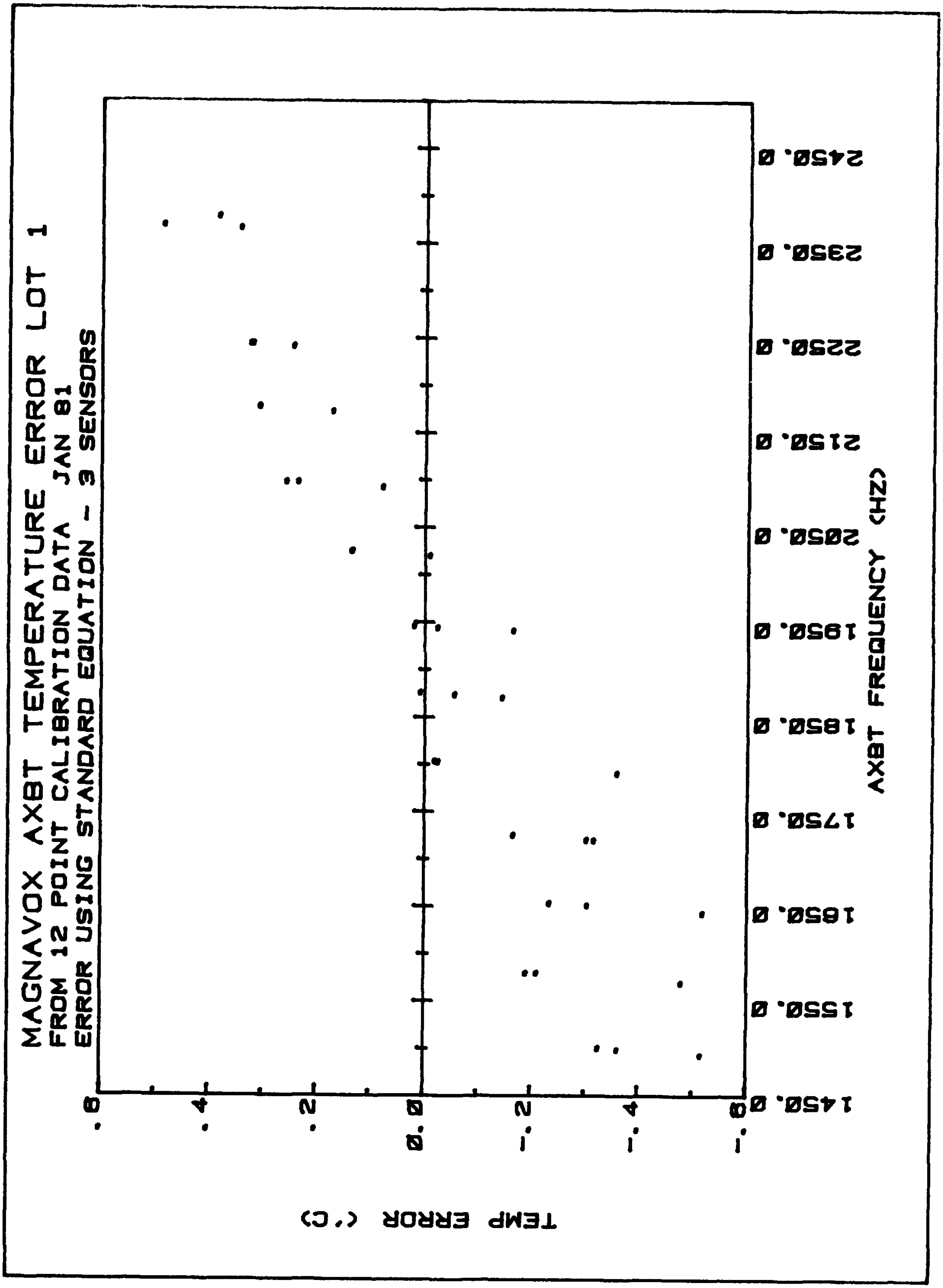


GRAPH 36

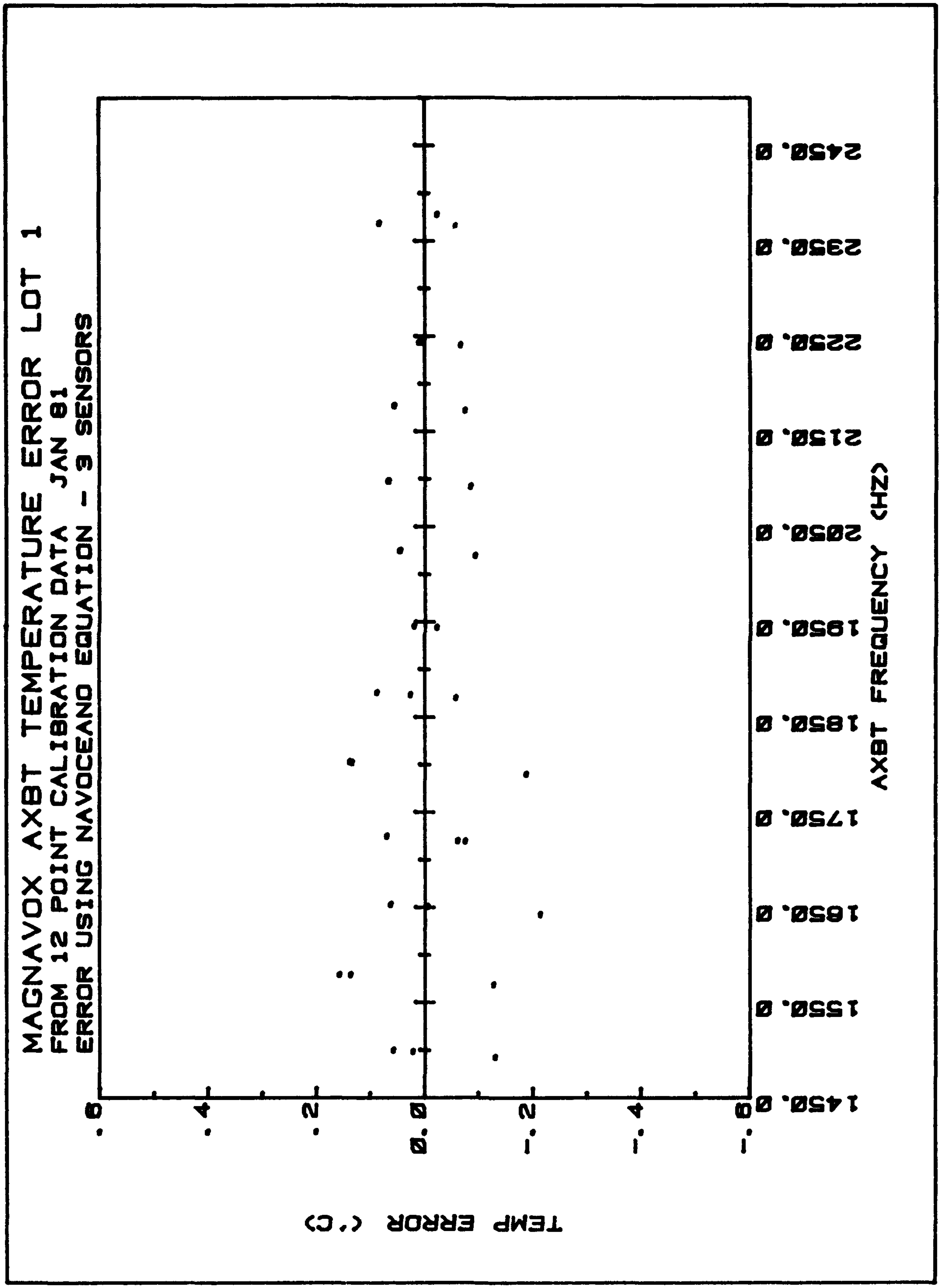


SIPPICAN AXBT TEMPERATURE ERROR
FROM 4 POINT CALIBRATION DATA DEC 80
ERROR USING NAVOCEANO EQUATION - 37 SENSORS
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

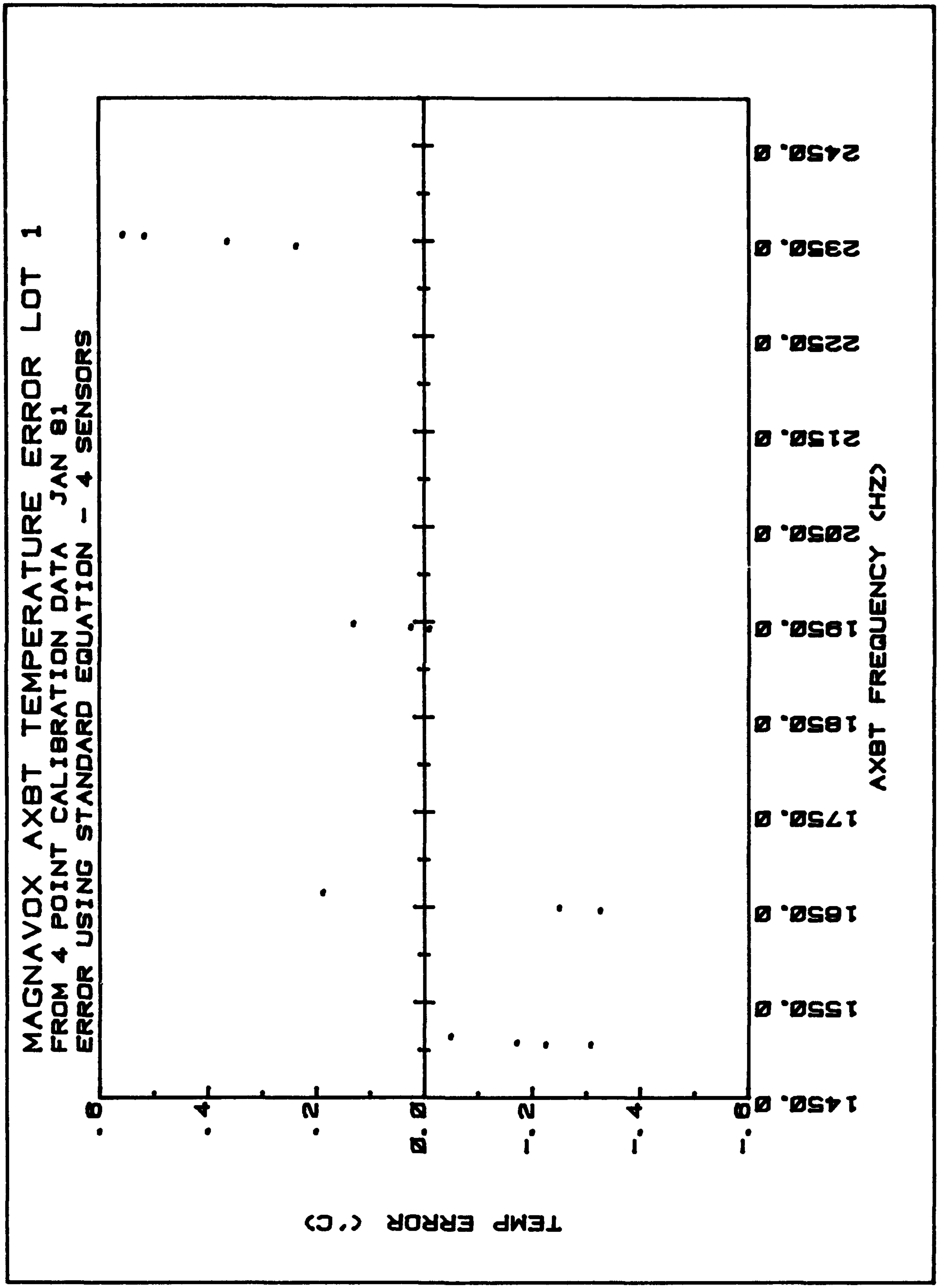
GRAPH 37


MAGNAVOX AXBT TEMPERATURE ERROR LOT 1
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 3 SENSORS
TEMP ERROR (°C)
AXBT FREQUENCY (HZ)
.8
.4
.2
0.0
-.2
-.4
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 38

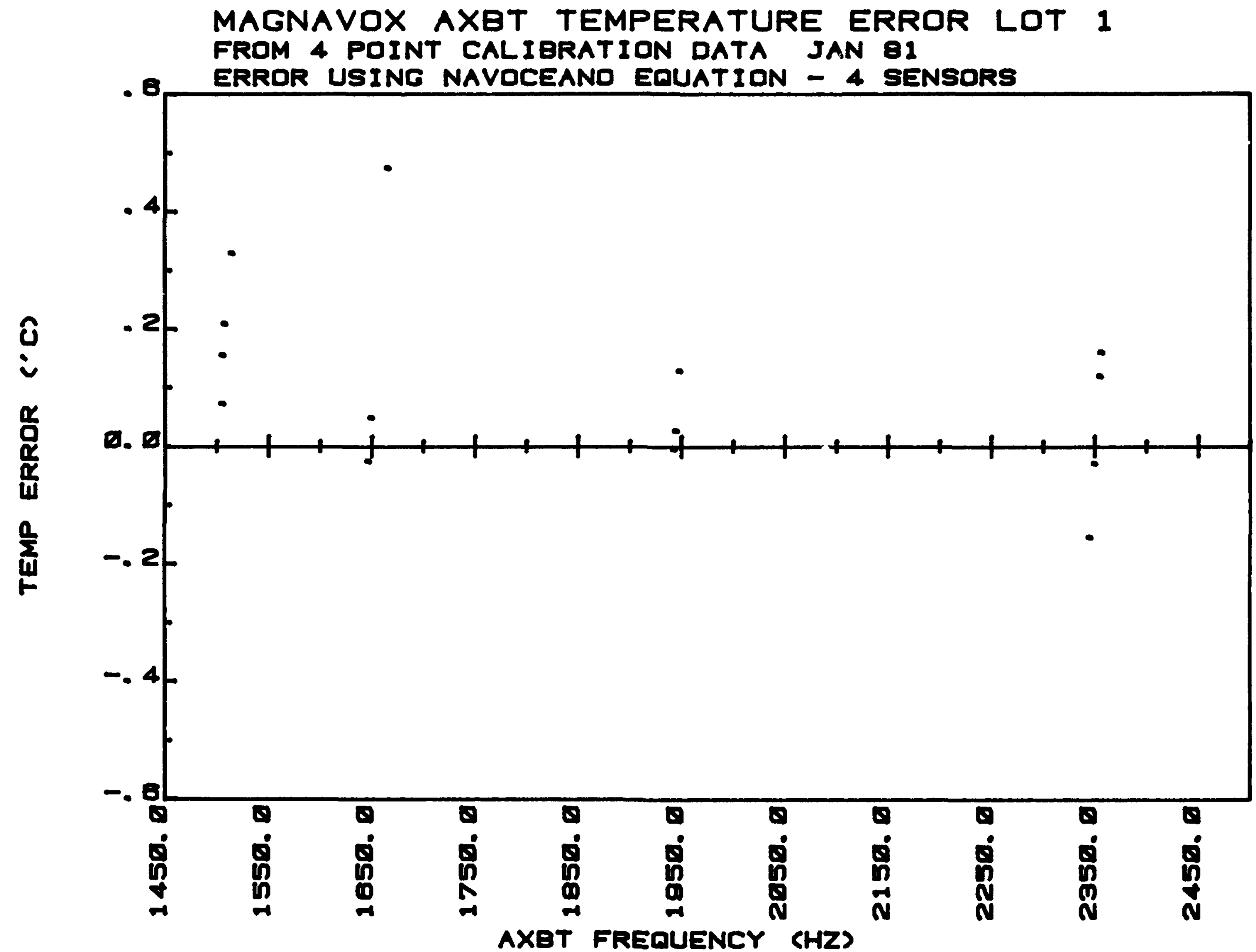

MAGNAVOX AXBT TEMPERATURE ERROR LOT 1
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 3 SENSORS
AXBT FREQUENCY (HZ)
TEMP ERROR ('C)

GRAPH 39



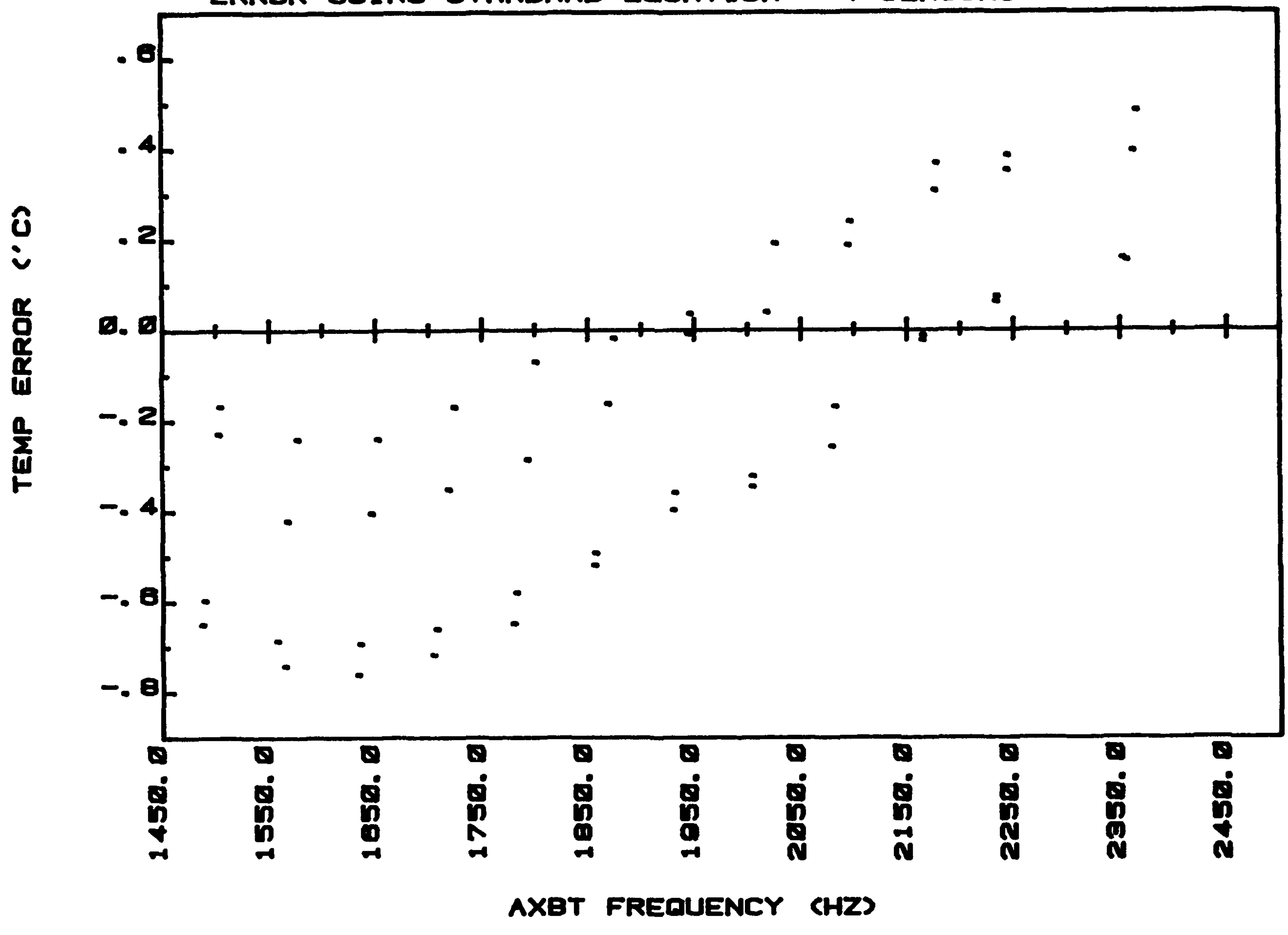
MAGNAVOX AXBT TEMPERATURE ERROR LOT 1
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 4 SENSORS
TEMP ERROR (°C)
.8
.4
.2
0.0
-.2
-.4
-.8
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 40

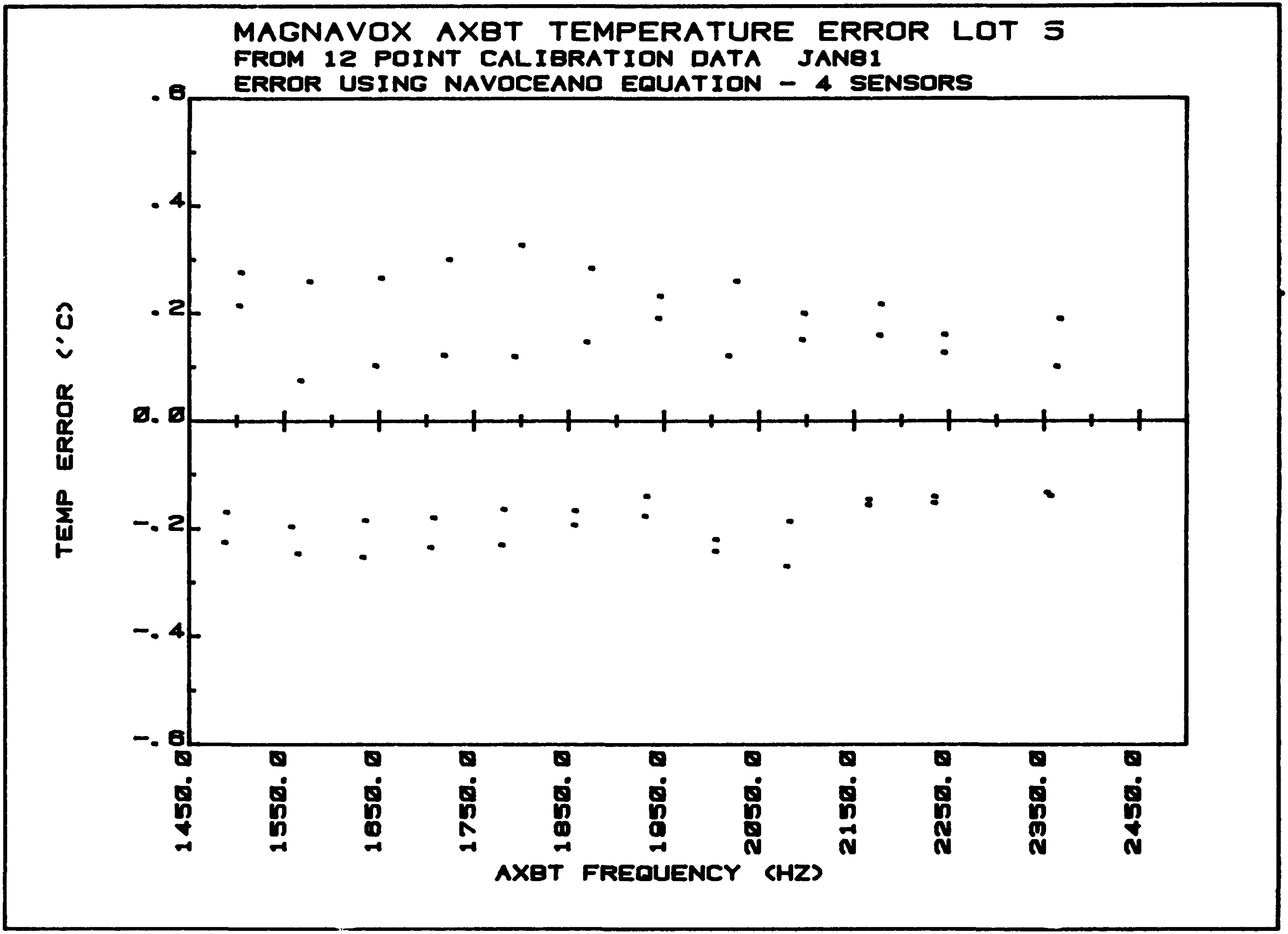

MAGNAVOX AXBT TEMPERATURE ERROR LOT 1
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 4 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 41

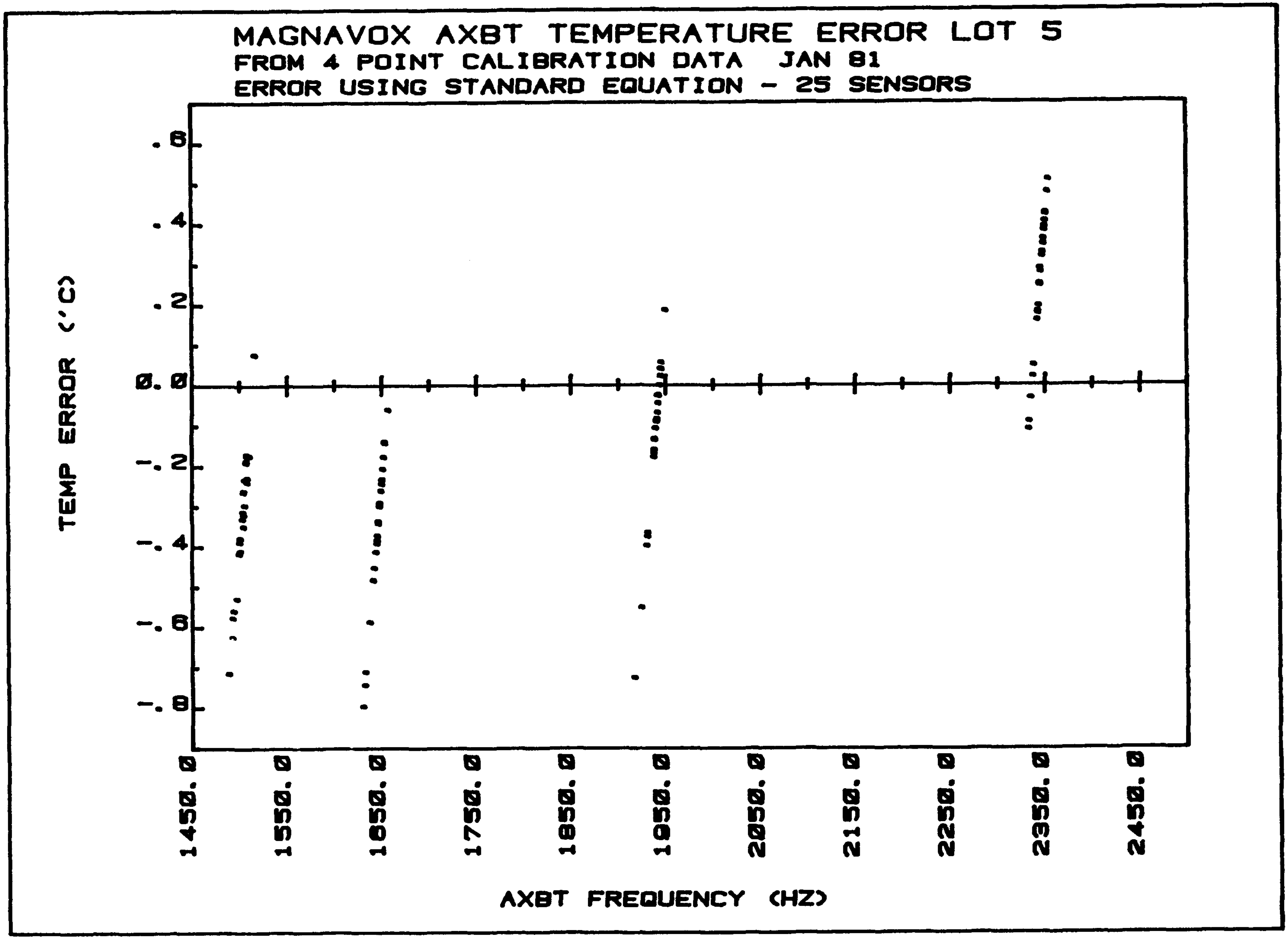
MAGNAVOX AXBT TEMPERATURE ERROR LOT 5
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 4 SENSORS



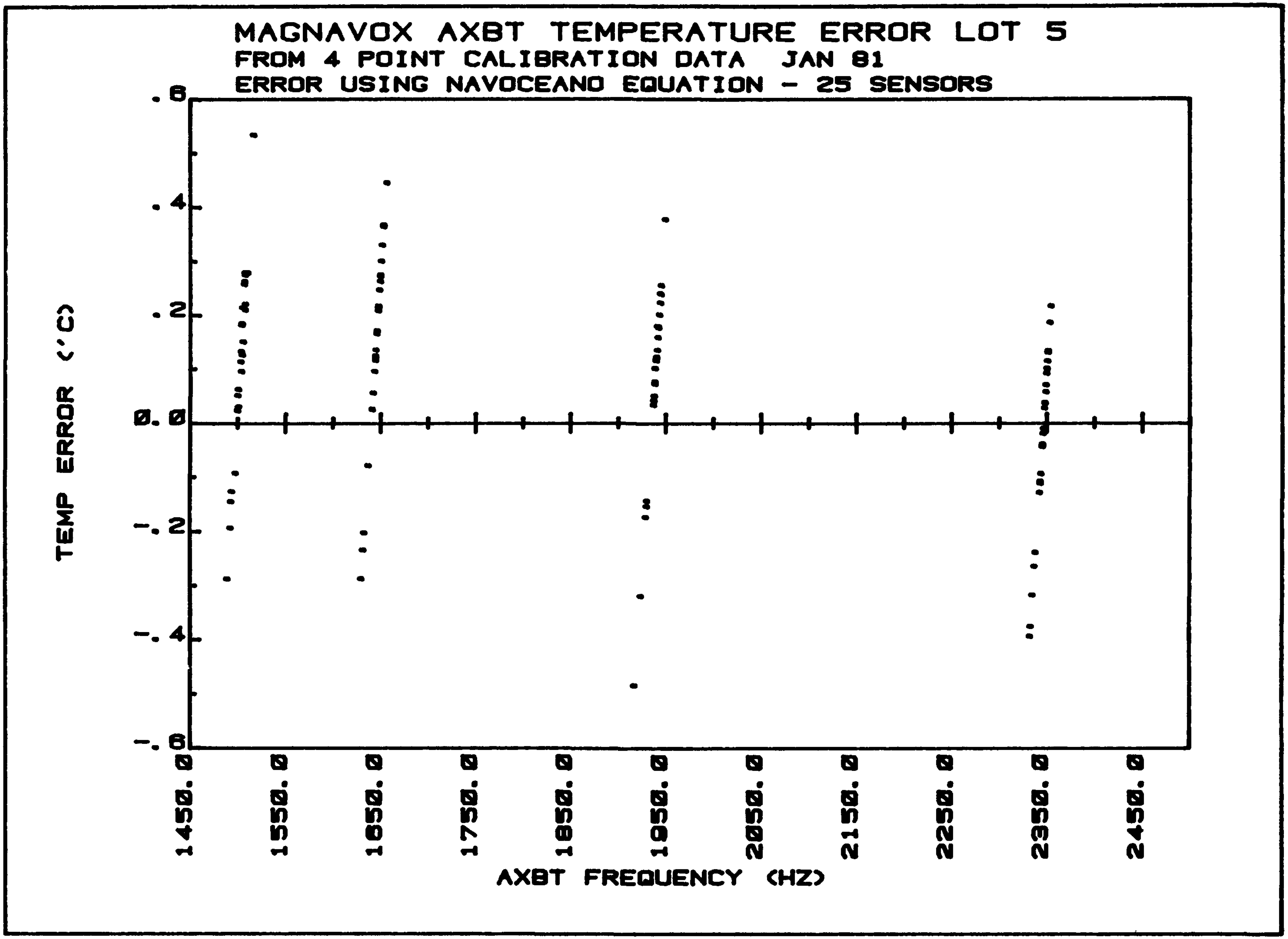
GRAPH 42


MAGNAVOX AXBT TEMPERATURE ERROR LOT 5
FROM 12 POINT CALIBRATION DATA JAN81
ERROR USING NAVOCEANO EQUATION - 4 SENSORS
TEMP ERROR (°C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

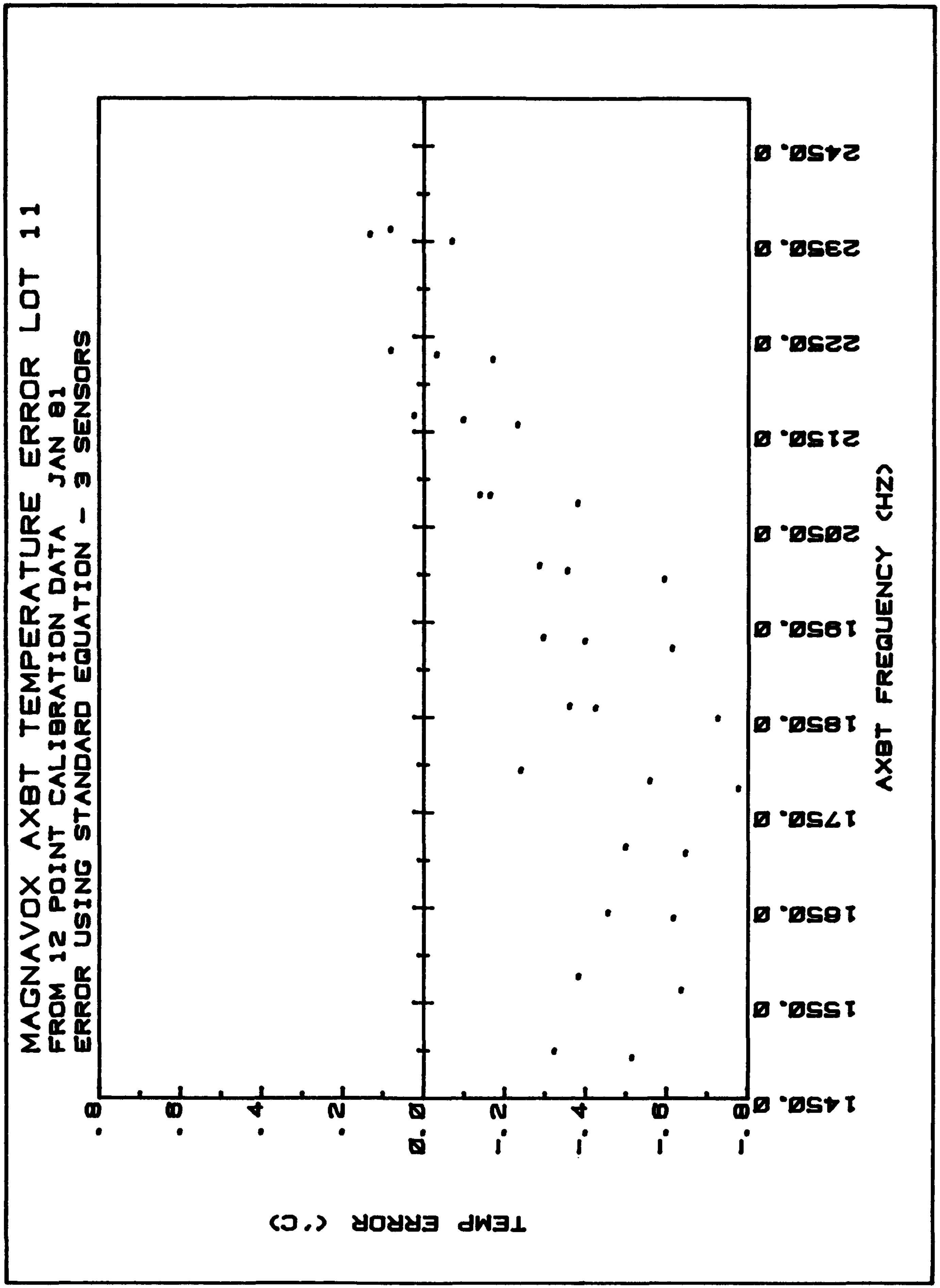
GRAPH 43


MAGNAVOX AXBT TEMPERATURE ERROR LOT 5
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 25 SENSORS
TEMP ERROR ('C)
.8
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 44

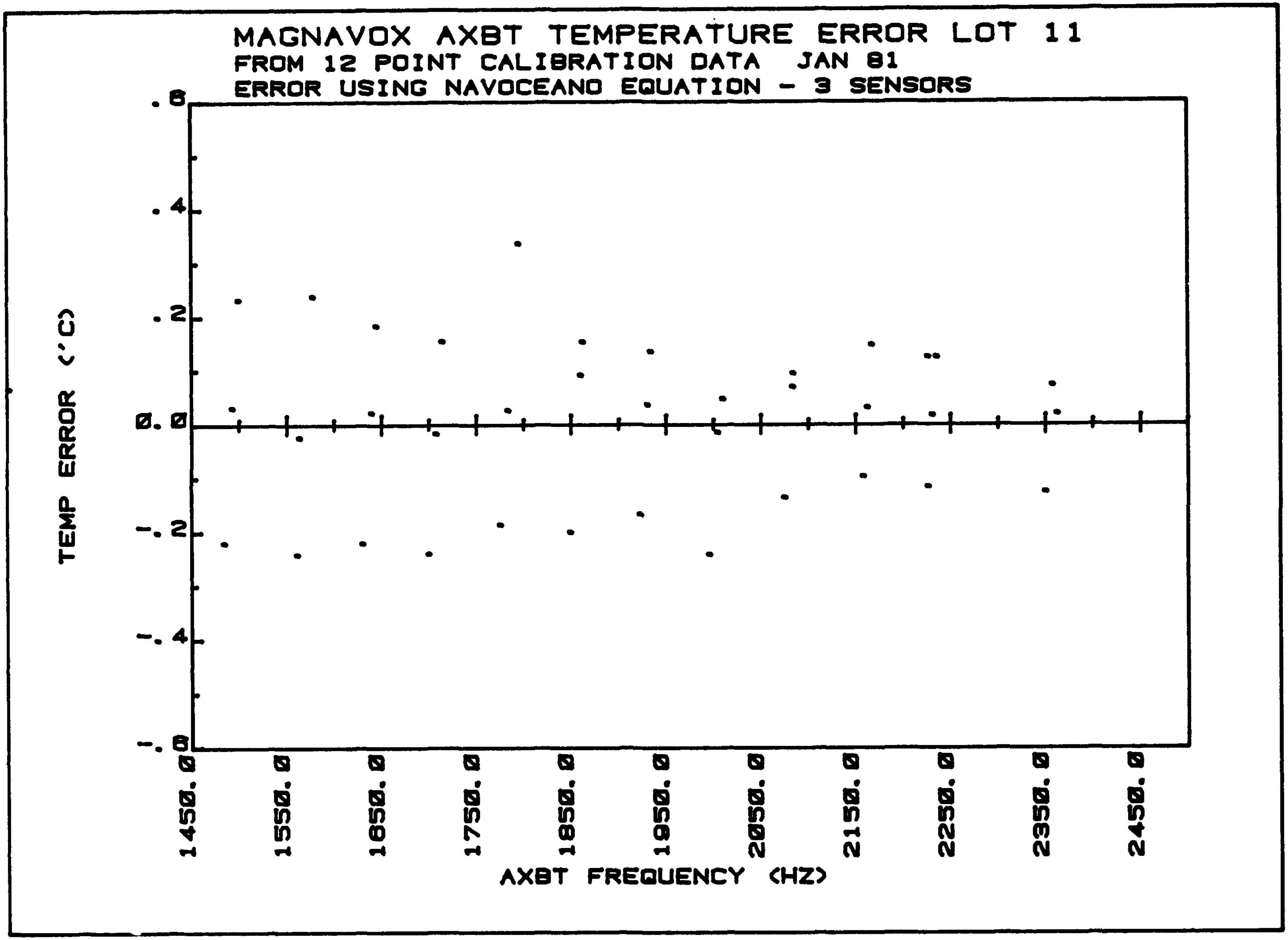

MAGNAVOX AXBT TEMPERATURE ERROR LOT 5
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 25 SENSORS
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 45

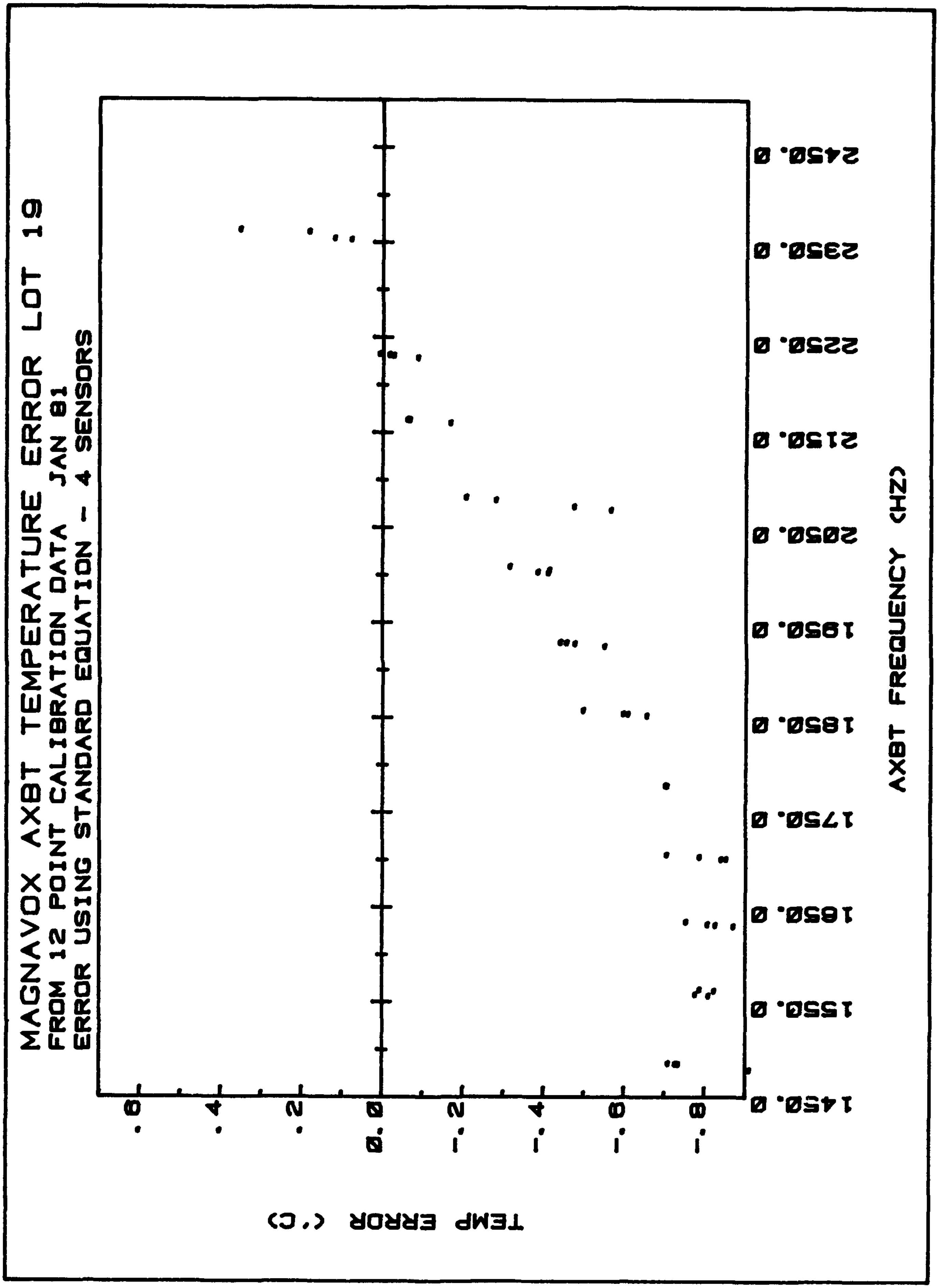


MAGNAVOX AXBT TEMPERATURE ERROR LOT 11
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 3 SENSORS
AXBT FREQUENCY (HZ)
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8

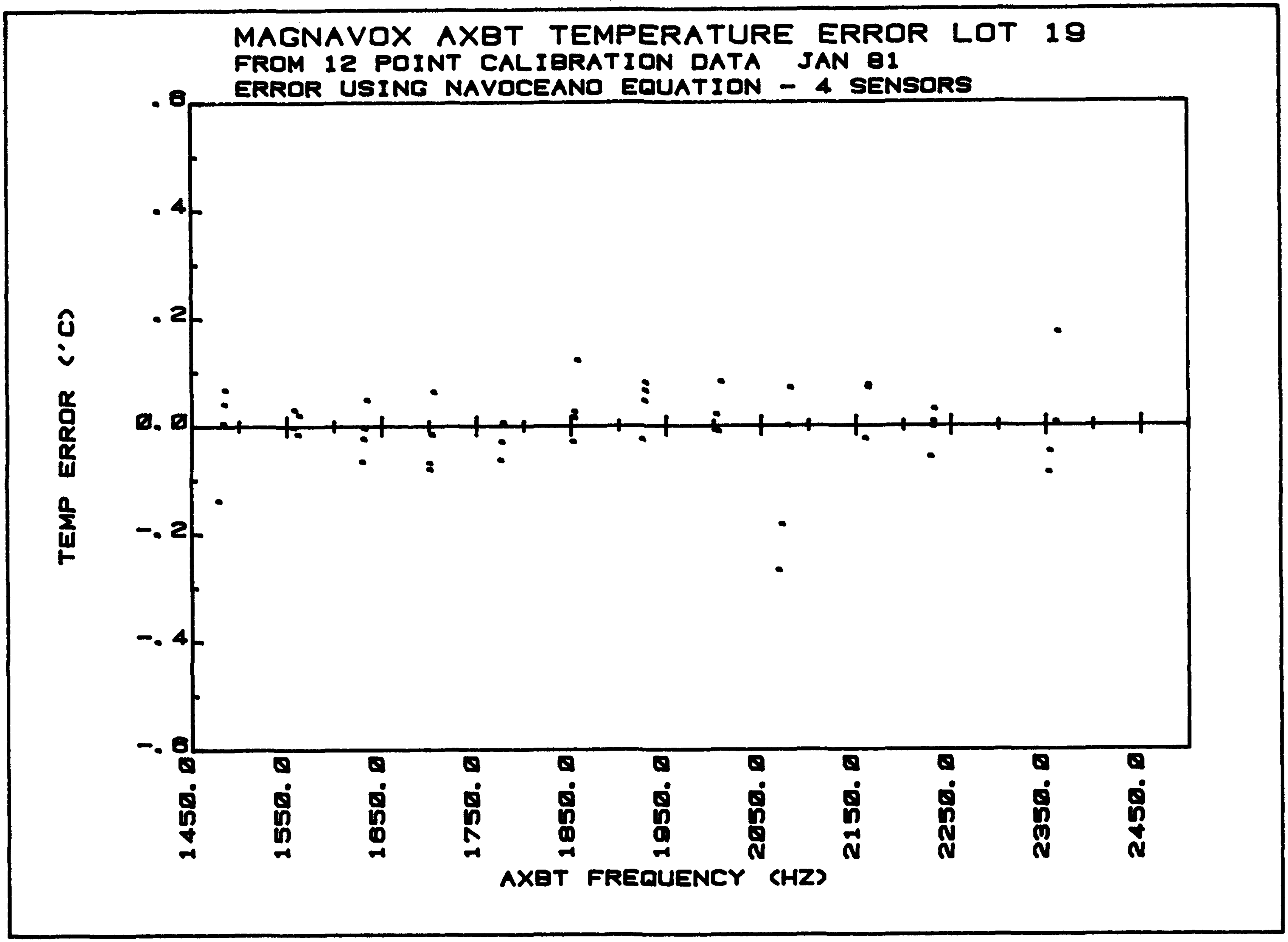
GRAPH 46


MAGNAVOX AXBT TEMPERATURE ERROR LOT 11
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 3 SENSORS
.6
.4
.2
0.0
-.2
-.4
-.6
TEMP ERROR (°C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

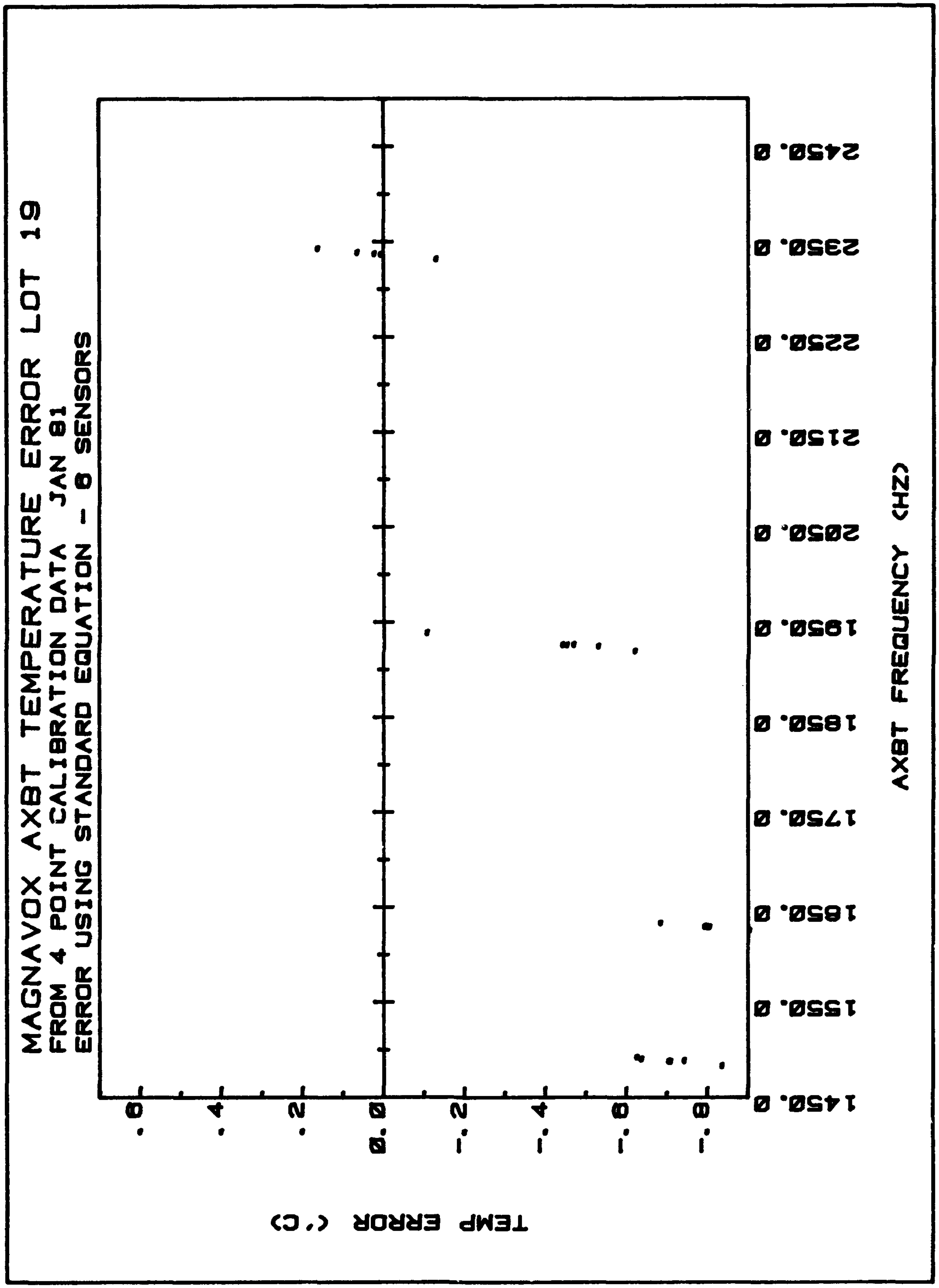
GRAPH 47


MAGNAVOX AXBT TEMPERATURE ERROR LOT 19
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 4 SENSORS
TEMP ERROR ('C)
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

GRAPH 48

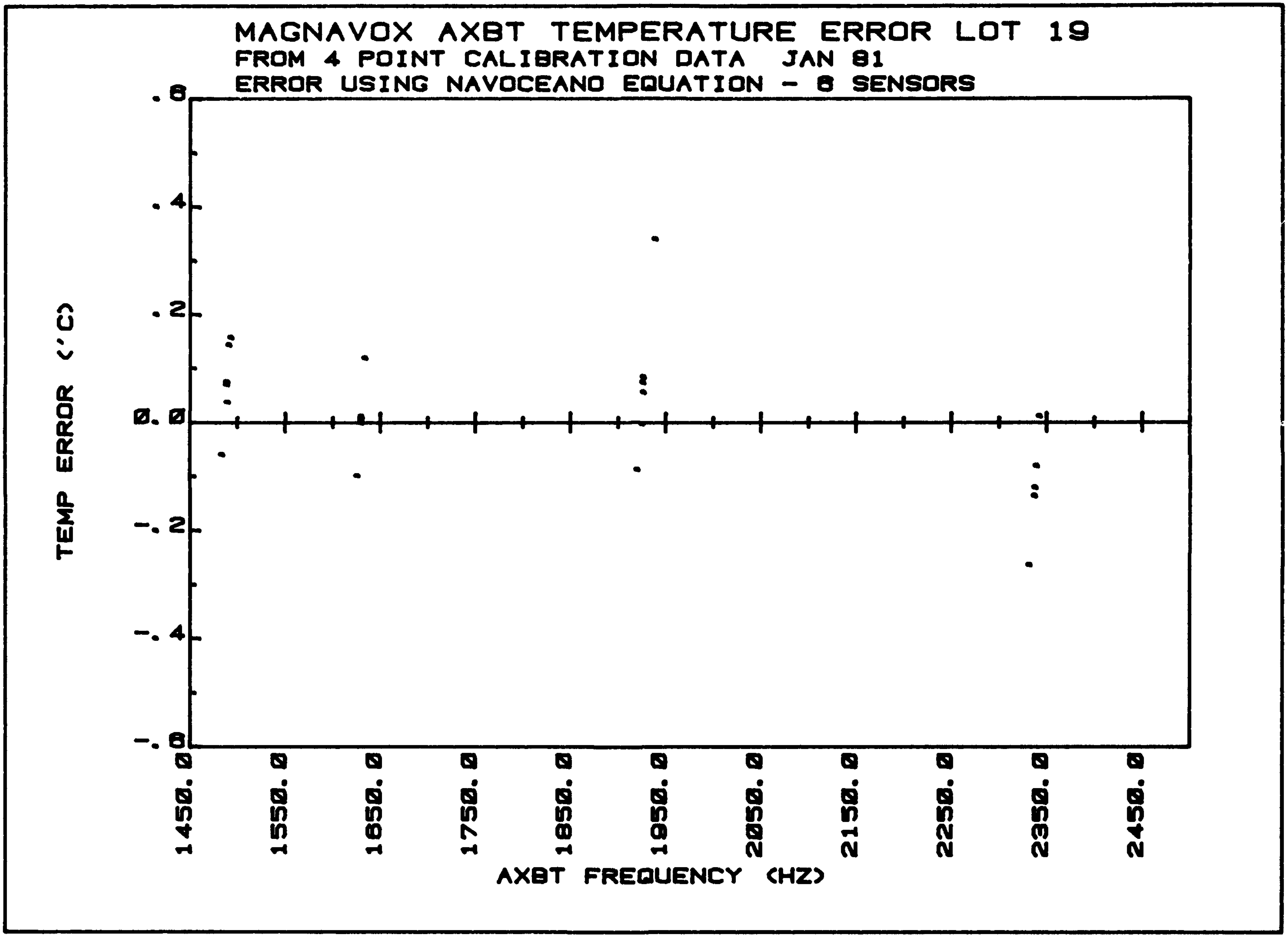

MAGNAVOX AXBT TEMPERATURE ERROR LOT 19
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 4 SENSORS
.8
.4
.2
0.0
-.2
-.4
-.8
TEMP ERROR ('C)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 49

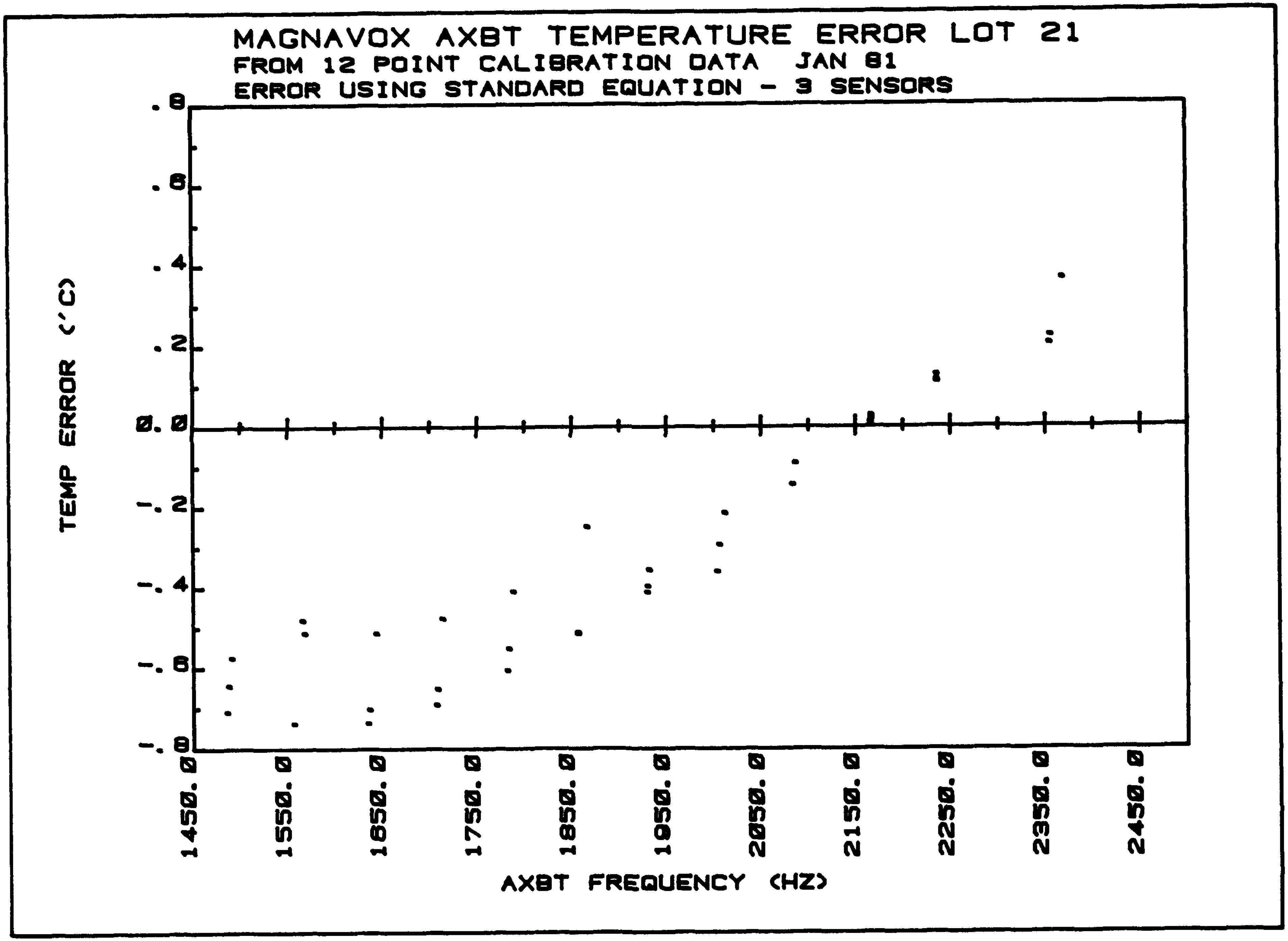


MAGNAVOX AXBT TEMPERATURE ERROR LOT 19
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 8 SENSORS
TEMP ERROR ('C)
AXBT FREQUENCY (HZ)
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0

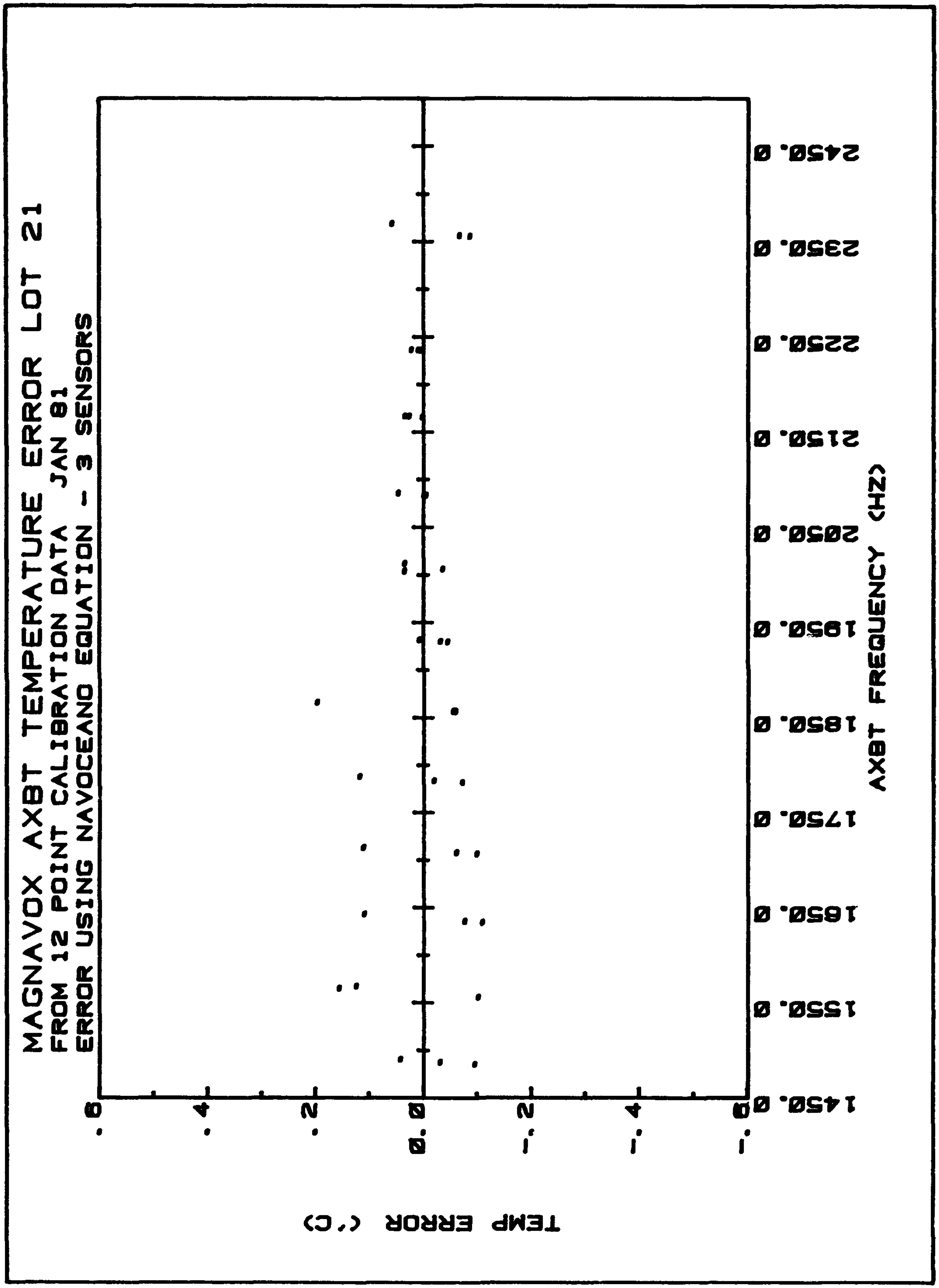
GRAPH 50


MAGNAVOX AXBT TEMPERATURE ERROR LOT 19
FROM 4 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 8 SENSORS
TEMP ERROR ('C)
.8
.4
.2
0.0
-.2
-.4
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

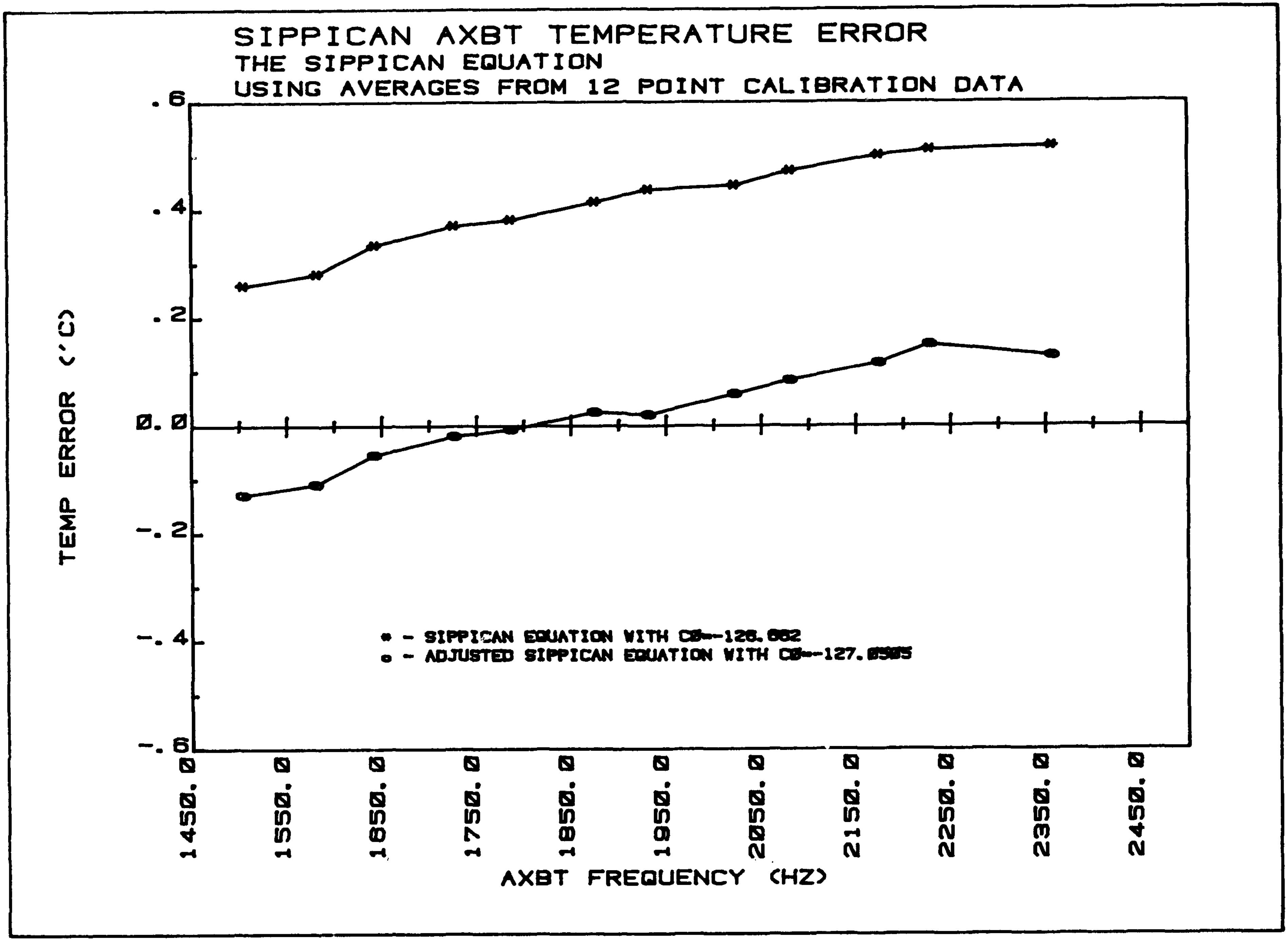
GRAPH 51


MAGNAVOX AXBT TEMPERATURE ERROR LOT 21
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING STANDARD EQUATION - 3 SENSORS
TEMP ERROR ('C)
.8
.6
.4
.2
0.0
-.2
-.4
-.6
-.8
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
AXBT FREQUENCY (HZ)

GRAPH 52


MAGNAVOX AXBT TEMPERATURE ERROR LOT 21
FROM 12 POINT CALIBRATION DATA JAN 81
ERROR USING NAVOCEANO EQUATION - 3 SENSORS
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
TEMP ERROR (°C)
.6
.4
.2
0.0
-.2
-.4
-.6

GRAPH 53


SIPPICAN AXBT TEMPERATURE ERROR
THE SIPPICAN EQUATION
USING AVERAGES FROM 12 POINT CALIBRATION DATA
TEMP ERROR ('C)
.6
.4
.2
0.0
-.2
-.4
-.6
AXBT FREQUENCY (HZ)
1450.0
1550.0
1650.0
1750.0
1850.0
1950.0
2050.0
2150.0
2250.0
2350.0
2450.0
* - SIPPICAN EQUATION WITH C0=-126.882
o - ADJUSTED SIPPICAN EQUATION WITH C0=-127.0505

GRAPH 54

APPENDIX B

TABLES

Tables 3 - 137 were deleted from report to reduce the size. Copies of this data are available upon request.

TABLE 1

TEMP. OUTPUT (°C) VS POWER IN					
SIPPICAN	SENSOR VOLTAGE (DC)				
SENSOR	13 V	12 V	11 V	10 V	9 V
1	26.476	26.348	26.194	25.974	25.691
181	24.936	24.843	24.711	24.550	FAIL
110	24.875	24.789	24.668	24.456	FAIL
170	24.828	24.739	24.607	FAIL	FAIL
150	25.218	25.123	24.982	24.779	FAIL
103	24.914	24.818	24.723	24.575	FAIL
101	25.001	24.904	24.808	24.662	FAIL

TABLE 2

MAGNAVOX – T_{STD} OUTPUT (C) vs POWER INPUT						
	SENSOR VOLTAGE (DC)					
SENSOR	12 V	11 V	10 V	9 V	8 V	7 V
22713	13.651	13.684	13.754	13.784	13.961	FAIL
7356	13.592	13.640	13.710	13.761	13.820	FAIL
75	14.017	14.071	14.127	14.189	14.253	14.505

APPENDIX C

CURVE FITS

* Deleted from this report.
Copies available upon request.

DISTRIBUTION LIST

COMNAVOCEANCOM	1
NRL	1
NORDA	1
NAVOCEANSYSCEN	1
COMOCEANSYSLANT	1
COMOCEANSYSPAC	1
COMNAVAIRSYSCOM	1
UC/SIO	1
UW/DO	1
OSU/SO	1
JHU	1
WHOI	1
MAGNAVOX	1
HERMES	1
SIPPICAN	1
DMAODS	1
DTIC	12

TR-277

JANUARY 1982

An Evaluation of the Airborne Expendable Bathythermograph (AXBT, SSQ-36 BTS)